PORTABLE DATA

RECORDER SYSTEM

DESIGN AND EVALUATION

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Introduction

The concept and preliminary design of a portable data recorder was first defined by Maurice Funke and reported in HD-TM-78-9 entitled "Preliminary Design of a Portable Programmable Data Recorder". Certain goals were set initially, such as simplicity, a cost of $1,000 per unit, battery operation, the ability to record all data pertinent to any platform or rig, the ability to perform inspection in random sequence, and the ability to enter numerical data, alphameric text, and spoken comments. As this report will show, each of these requirements places demands upon the hardware and software which interact with each other and with human factors.

The data requirements were the principal factor in software design, Hardware specifications (such as battery operation with self-contained batteries giving 3-5 day life) also dictated much of the software design. This interaction of hardware and software design will strongly influence future concepts as microprocessors become available with different circuit architecture. Finally, there was the human factors assessment of the likelihood of achieving USGS goals. Each of these aspects is addressed in terms of a) the necessary, b) the possible, and c) the economically feasible.

CHAPTER I. SOFTWARE DESIGN OF A PORTABLE DATA RECORDER

1.1.0 Overview

This chapter describes the software design considerations and specifications for a portable data recorder (PDR) for the United States Geological Survey (USGS). The design considerations were influenced by three major factors.

a. Functionality of Data Recorder
b. Hardware to be used
c. Human Factors

It is assumed that the reader is already familiar with USGS's motivational factors for initiating the PDR requirements. Therefore, the oil rig data collection process will not be discussed, and the reader is referred to reference 1 for more preliminary design and background information. The hardware and the human factor issues are discussed in detail in the following chapters and therefore, will only be presented as they pertain to the design aspects of this software architecture.

1.2.0 Design Considerations

In designing the software for the PDR it was necessary to consider the functional requirements, the hardware configuration, the data requirements, and the communication requirements. All of these considerations together made up the nucleus for specifying the software prototype for the PDR.

1.2.1 Functional Requirements

The PDR as defined in reference 1 has five major functions. These functions are as follows:

a. Manual data entry/editing
b. Display of data and prompts
c. Storing verbal data
d. Recalling verbal data
e. Transfer of data to and from a central computer system

The manual data entry and editing process is via a small hand-held keyboard. The data entry process must be interactive, easy to learn and easy to use. Basic verbs for entry and editing should be called up via single labeled keystrokes to minimize operational procedures on the part of the inspector. Data display must be informative, easy to read, yet concise enough to fit within a small display area. Verbal data must be stored on magnetic tape in variable length analog records. This last requirement could be satisfied by a sequential record system. Verbal comments should be associated with data entry items and "pseudo-randomly" accessible. This then requires a linked record system of some kind. All data must be "instantaneously" available for the inspectors use in order for the inspector to make sound decisions in the inspection procedures. Thus a fast access storage media is a necessary requirement. Due to hardware restrictions to be discussed later, the research prototype PDR used a semiconductor random access memory.

The final functional requirement is that of data communications. The PDR data set is only a small subset of a much larger data set. This larger data set is stored and manipulated on a mainframe computer. A means must be provided to downline load the portable data recorder with specific data for a specific inspection to be performed by the inspector. At inspection completion, the PDR must have the capability of sending the updated data back to the mainframe computer for analysis.

1.2.2 Prototype Hardware Configuration

At the time that the research was initiated for this project (December 1977), a limited selection of commercial hardware was available to meet the criteria required by the PDR environment. (See HDL-TM-78-9). A summary of the hardware selected for prototype research was as follows. The processor selected was the RCA/COSMAC 1802. A limited amount of read only and random access memory was provided in the form of 4K and 1K chips. A slow analog cassette recorder (300 BPS), was selected for offline storage and a forty key Texas Instrument calculator style keyboard was chosen as the primary input device. The display selected consisted of two rows of 20 light emitting diodes (LED) alphanumeric ASCII digits. A two speed switch selectable RS232 serial communications line was provided for remote data communications. A low speed line (300 BPS) would be used for telephone communications and a high speed line (9600 BPS) would be used for direct computer connections.

1.2.3 Data Requirements

Based upon interviews with inspectors, it was found that the oil inspection procedure is a constantly evolving process. A general set of procedures have been developed by USGS as the nucleus for these inspection procedures. As the oil industry changes, so must the inspection procedures change. The data requirements for the PDR must always reflect the current state of the inspection procedures. This requires that the PDR be able to manage many data relationships in a very general fashion. The nature of the data is broad enough that a small generalized data base management system (DBMS) is required to be built into the software as the nucleus for the PDR.

The data should be structured so that an inspector can quickly find a data within a particular data set relationship. Once loaded, the inspector has to be able to modify the data record, delete the data record, or insert new data records in the data set. The inspector then has to be able to go on to another record within the data set or change to another data set relationship. The PDR has to have the capability of adopting new data relationships or modify old data relationships as requirements change. These adaptations and modifications should be possible to implement with a minimum reprogramming effort.

The data has to externally represent the manual data inspection forms currently in use by USGS. Internally, it should be represented so that it can be easily transformed into sequential records matching exactly the data formats expected by the already existing mainframe data management programs.

The data to be stored in the PDR is only a subset of a much larger set of data. Figure 1 illustrates conceptually how the data is to be distributed. At the top level is the central data processing system where all of the USGS oil inspection data is stored. Subsets of this data are transmitted to local area stations where the data is partially duplicated. Within the area office, the local computer translates the data into a format that the PDR can easily use and loads the PDR cassette tape with a specific inspection procedure. Figure 2 shows a functional view of the local database processor. Besides serving the function of a translator, it can be used as a database query and analysis processor to aid the inspector in performing the tasks.

The inspections are logically divided by oil complex. Examples of inspection forms are shown in Appendix A. Each data set within a PDR pertains to only one complex. Each complex may consist of a number of platforms (typically one or two) and each platform consists of several structures. Each structure may contain several decks and each deck is composed of a number of slots. The data must be organized to represent these physical relationships.

There are currently nine general areas of inspection that the data must cover.

a. Complex Identification
b. Enforcement Action
c. Pipelines
d. Well Bay and Field Records
e. Atmospheric Vessels
f. Pumps and Compressors
g. Fired Vessels
h. Header

Figure 3 shows one way that this data can be structured internally within the PDR's general data base management system. The system sets required in these relationships are minimally SYSTEM-COMPLEX, SYSTEM-ENFORCEMENT and SYSTEM-STRUCTURE. This allows the inspector to quickly attach to the data base in a familiar place.

Because enforcement actions are related not only to the particular complex, but to a particular inspection procedure, there is a need for a set relationship between the various inspection area records and the enforcement records.

The data contained within the actual records themselves must provide for at least the following data types.

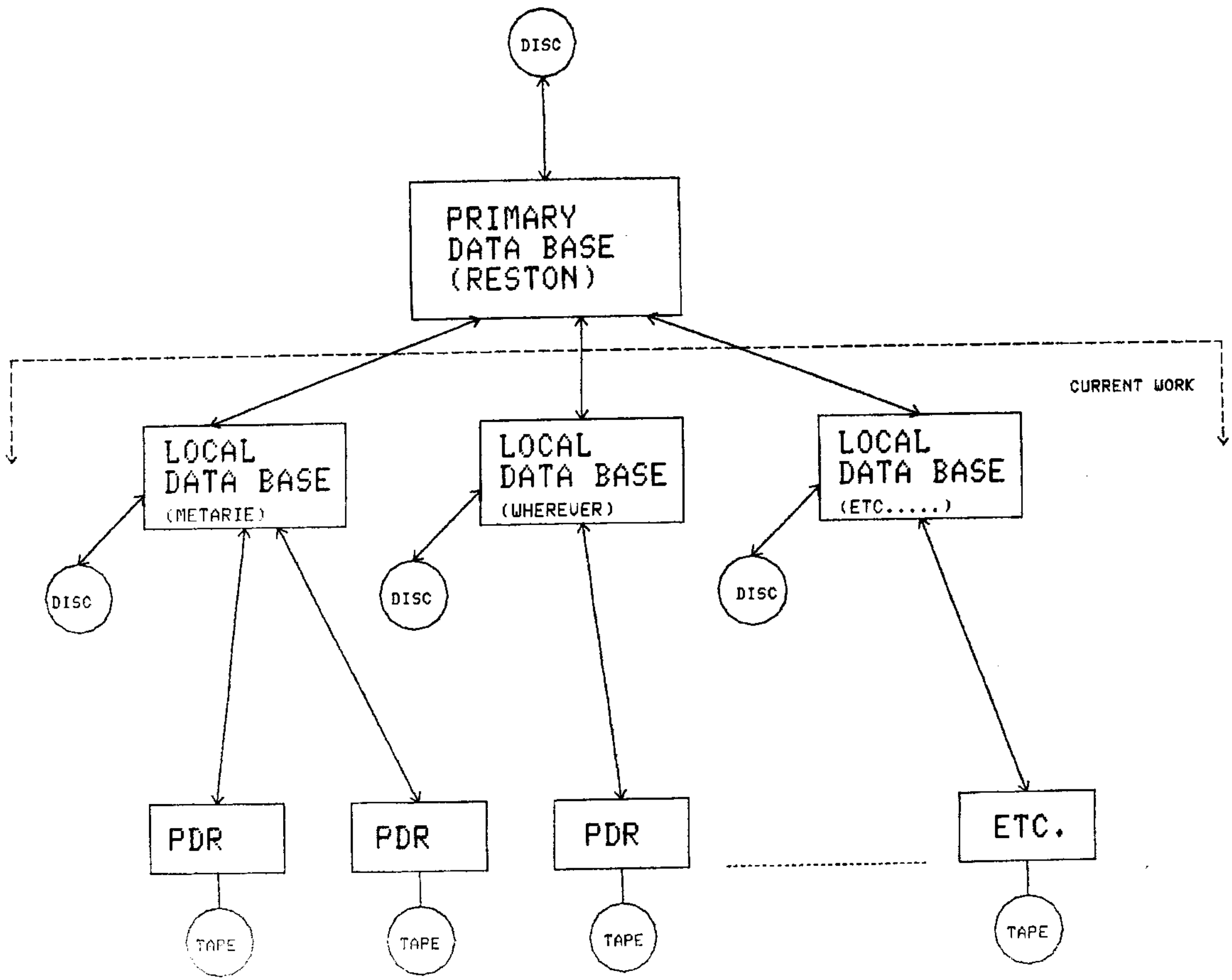

FIGURE 1. Distibuted Database

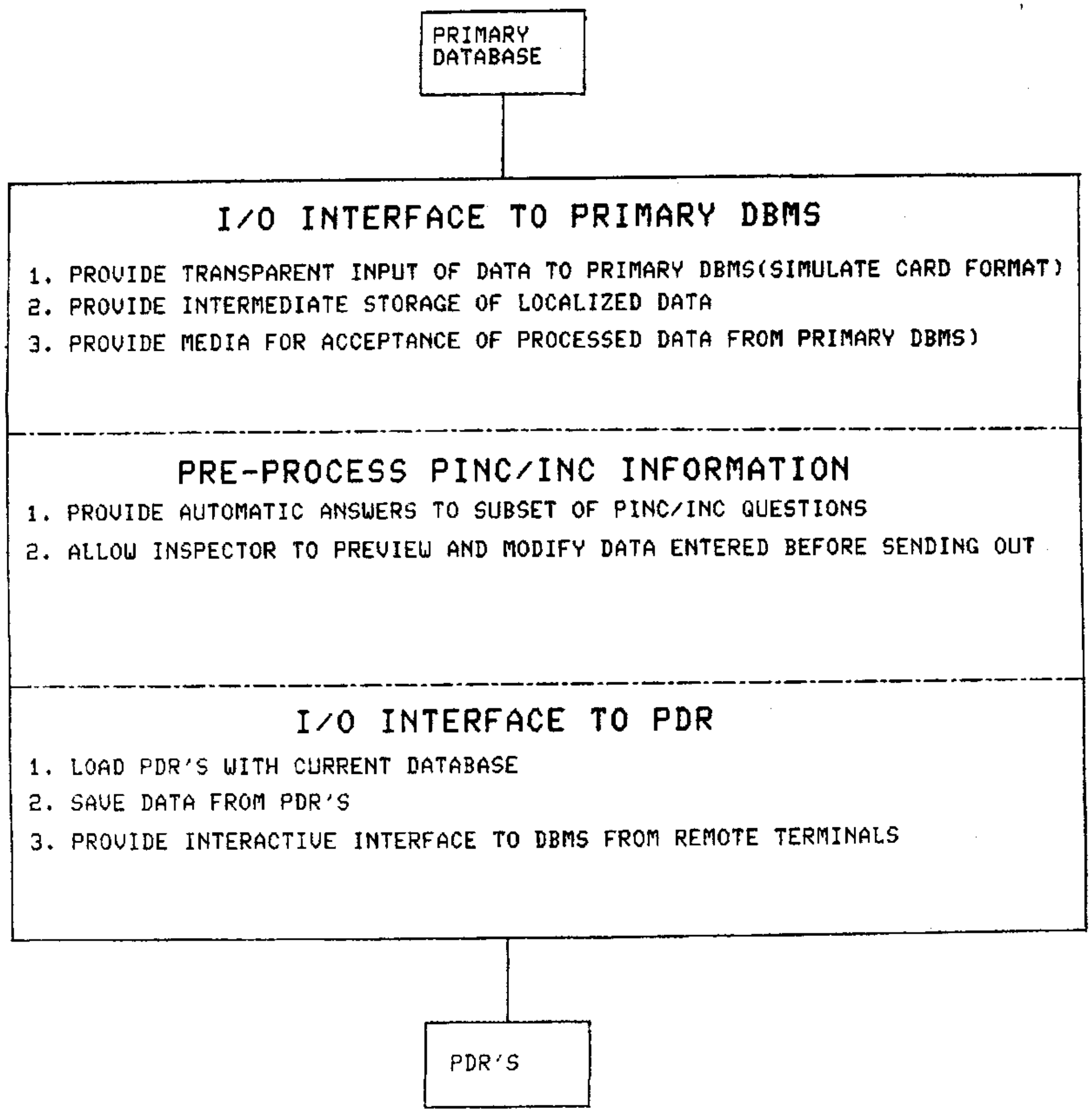

FIGURE 2. FUNCTIONAL REQUIREMENTS OF LOCAL DATA BASE SYSTEM

1. General Alphanumeric
2. Numeric Only
3. Logical

In addition the following special data types would be desirable but not absolutely necessary.

1. Date
2. Voice Pointer
3. Floating Point

Because of the large amounts of general textual data involved, data compression techniques should be considered wherever possible. Numeric data should be stored in binary form and logical data should be stored in single bit strings wherever possible.

Associated with each record type (or set type) should be useful text information to allow the inspector to view the data in a context familiar to his modes of operation.

The data requirements for analog vocal data are minimal. The verbal records should be organized so that the inspector may record each record sequentially as needed. Each record should be associated with a real data item within the digital data set and should have the capability of being recalled either randomly or sequentially with respect to the associated digital data item.

1.2.4 Communication Requirements

Data communications are required for loading data pertaining to a particular inspection into the PDR before inspection time. After the inspection is completed the inspectors newly entered and modified data is sent back to the local computer database. To minimize the volume of data transferred, the data should be formatted into binary records wherever possible. To insure data reliability, a simple protocol should be employed to verify data transfers.

A byte oriented protocol is easily implemented and usually transportable to other hardware configurations. A minimal communication protocol should look as follows:

STX RECLEN data CHKSUM

where

STX is the start of text ASCII character
RECLEN is the length of the data (MAX=225)
data is the actual data
CHKSUM is an 8-bit checksum

Upon transmission of each data record, the receiving machine should accumulate and compare checksums. If the checksums do not agree then an ASCII non-acknowledge (NAK) should be sent, otherwise an acknowledge (ACK) should be sent. After some predetermined number of consecutive NAK's have been sent, the operator should be notified and the communication discontinued. If a NAK is sent, the transmitter should resend the message. If a RECLEN is not fulfilled, the receiver should time out and notify the operator.

1.3.0 Prototype Software Development

A prototype of the software was developed using the considerations of the previous section. Feasibility was shown without meeting all software goals. In particular, nothing was done in the area of data compression techniques, or varying methods of data storage on cassette tape.

The software was restricted by the hardware available and did not encompass all data relationships. Presented in this section will be a brief discussion of the I/O system, command language interface, general data base management system and communication interfaces. Figure 4 illustrates the functional requirements organization of the PDR prototype software system.

The software was developed using the RCA CSDP cross assembler on a PDP 11/45 using RSX 11-D. Programs were stored both in PROM and in RAM. RAM was loaded via an RS232 line connected to the PDP 11. A memory resident debugging aid was written for the COSMAC to allow memory and register modifications, down line loading and breakpoint setting.

1.3.1 I/O System

The basic hardware configuration used in the prototype research model is shown in figure 5. I/O drivers were written for the cassette, and the serial communications on a programmed I/O basis. Drivers for the keyboard, clock and display were written on an interrupt basis.

1.3.1.1 Clock -

The real time clock is the only mechanism that can actually generate an interrupt to the COSMAC processor. When a clock interrupt occurs, three actions are performed.

1. Keyboard scanned
2. Display blinked
3. Clock updated

The clock update increments a software memory location on each interrupt to let the remaining software system know that time has elapsed. This is used for communication time outs and keyboard "typ-a-matic" (auto-repeat) and any other action that requires timing.

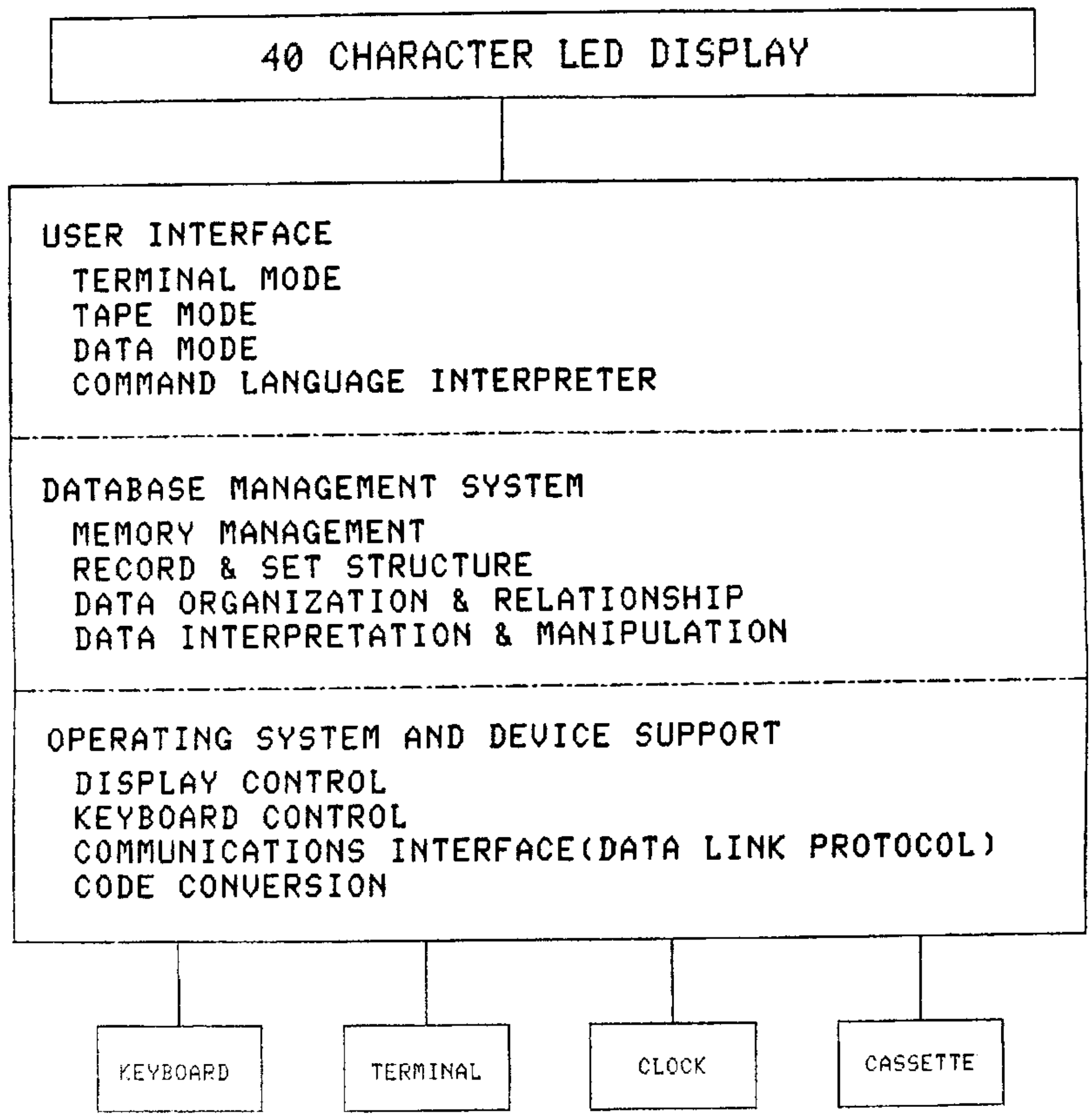

FIGURE 4. FUNCTIONAL REQUIREMENTS OF PORTABLE DATA RECORDER

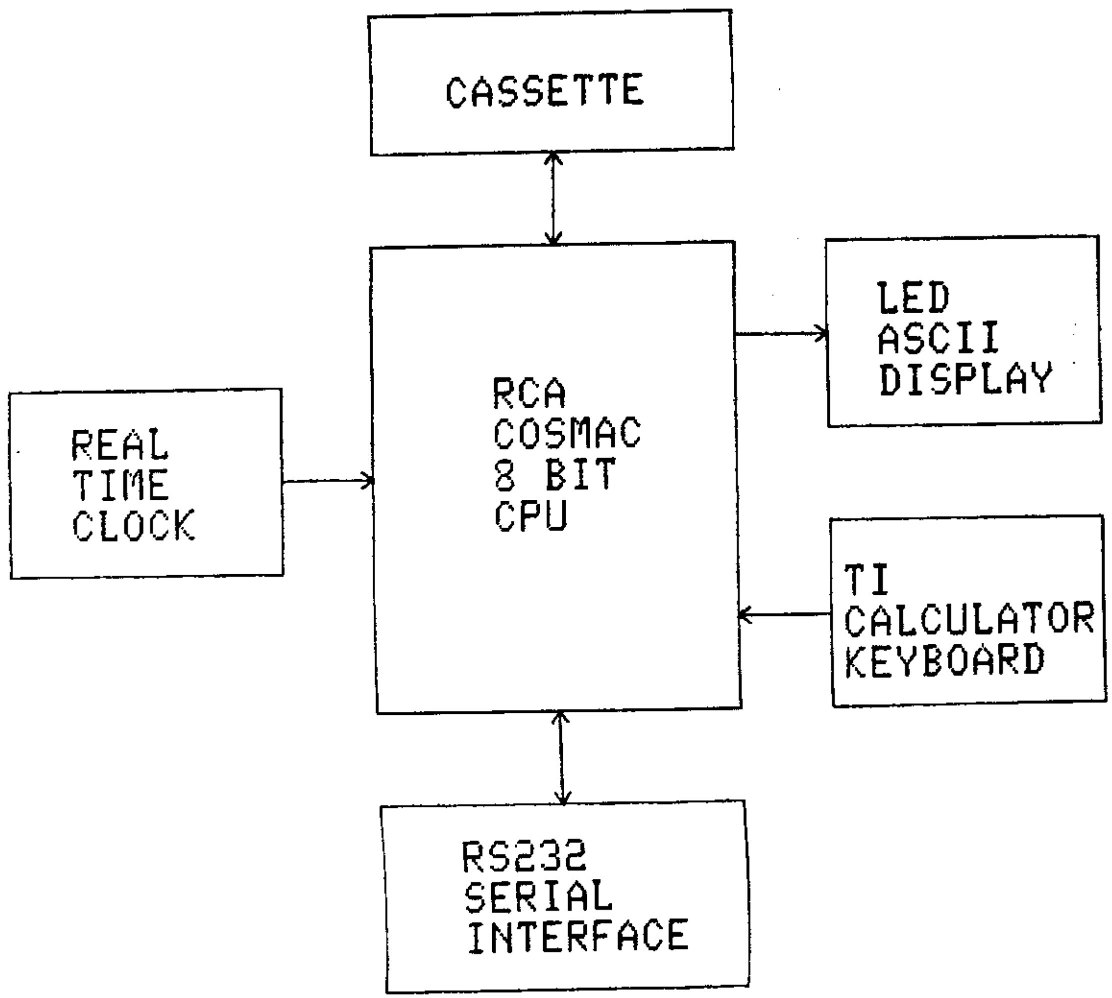

FIGURE 5 Prototype Hardware Configuration

1.3.1.2 Keyboard -

The keyboard of the prototype PDR is an extremely primitive device. Matrix logic along with timing and key "debouncing" algorithms were developed to validate legal keyboard entries. This logic can be found in the general interrupt service routine provided for the keyboard. After input is verified, several functions were provided for processing keyboard input.

1. Read the keyboard input
2. Translate keyboard to ASCII data
3. Convert keyboard to a command input
4. Typ-a-matic input

All keyboard input was treated as serial single character input as opposed to record oriented I/O. In this manner, single character inputs could be legal keyboard inputs triggering larger semantic processing actions. The keyboard and display for the prototype PDR are shown in Figure 6.

1.3.1.3 Display -

The display is divided into three logical display systems. Each display system maps to one of two physical LED displays. Each physical LED display contains 20 alphanumeric ASCII digits. Each logical record can contain up to 150 alphanumeric ASCII digits. In order to display 150 digits on a 20 digit display, horizontal scrolling has to be provided. Algorithms developed provided for the following functions.

1. Select logical record
2. Reset and clear display
3. Turn off display
4. Turn on display
5. Position to the front of the record
6. Position to the end of the record
7. Scroll left
8. Scroll right
9. Insert 1 character at end
10. Insert N characters at end
11. Insert into middle of display
12. Blink display

1.3.1.4 Cassette -

The cassette driver has to provide for both the storage and retrieval of verbal data as well as digital data. The driver was designed with the following functions.

PDR KEYBOARD PRELIMINARY LAYOUT

TOP ROW IS WITH CONTROL KEY
BOTTOM ROW IS WITHOUT CONTROL KEY

	1	2	3	4	5
8	. 1	+ 2	- 3	4	5
7	DATA 6	TAPE 7	TERM 8	LOGON 9	LOGOFF 0
6	SEND A	ABORT B	C	SAVE D	LOAD E
5	OLD F	NEW G	RESTORE H	CHECK I	J
4	FIRST K	LAST L	NEXT M	PREVIOUS N	ADD O
3	P	TOC Q	FIND R	S	T
2	U	V	W	X	Y
1	CONTROL	PLAYBACK VOICE	START LEFT	END RITE	SHUTDOWN Z

FIGURE 6. KAYBOARD AND DISPLAY FOR PROTOTYPE PDR

1. Move tape forward
2. Move tape backwards
3. Rewind tape
4. Write EOF
5. Turn on/off tape transport
6. Turn on/off microphone
7. Read data
8. Write data

Higher level functions were designed to load and dump the memory resident data base onto tape.

1.3.1.5 Serial Interface -

Using programmed I/O, algorithms were designed to provide the following functions in conjunction with the RS232 serial interface.

1. Read a character
2. Write a character
3. Read a record
4. Write a record

The RS 232 interface software will be discussed in more detail in the section pertaining to data communications.

1.3.2 Database Management System

The prototype database management system (DBMS) designed for the PDR prototype utilizes many of the concepts introduced in the Conference On Data System Languages (CODASYL) specifications for data base management systems. Since the software was to be implemented on a very primitive microprocessor, only a small subset of this specificaton was considered.

The ideas and basic spirit of the CODASYL system were retained. The DBMS is designed to allow for various types of network data structures and hierarchical data structures. This general structure allows for evolution of the PDR software as data requirements change with the inspection procedures.

The DBMS consists of two major portions. First there is a data definition language (DDL) for describing the various records and set relationships. Secondly, there is a data manipulation language (DML) for accessing and changing the data within the constructs of the defined data relationships.

1.3.2.1 The Data Definition Language (DDL) -

The DDL for the prototype PDR exists in a form much like a cross assembler for a low level development system. The DDL itself is written in FORTRAN and runs on the PDP 11/45 system. It generates output tables for the COSMAC DML runtime system in the form of COSMAC assembly language statements. These statements are assembled and linked with the run time system for the COSMAC and stored in PROM. Unless the set relationships or record descriptions are modified, these PROMS need never be reprogrammed.

The following constructs are provided in the prototype DDL. It is assumed that the reader is familiar with CODASYL database concepts.

1. TARGET (C[OSMAC]! F[ORTRAN]) comment field

This must be the first statement in the DDL to indicate what object code is to be generated for which target device.

2. RECORD <recordname> <comment field>

This statement declares a record type with the name <recordname>. The name must be eight characters or less. The first record name should always be SYSTEM with no associated data items.

3. ITEM <itemname> <itemtype> <itemlength> <comment field>

This statement is used to describe the items within a record. Item names (<itemname>) can be four characters or less. Item types (<itemtype>) include the following: A-alphanumeric; B-1 byte integer; I-2 byte integer; f-8 bits logical flip-flop fields. The <itemlength> is used to describe how many digits will be allowed in the LED display area for the item.

4. SET <setname> <ownername> <membername> <comment field>

This statement is used to declare a set relationship. The set names must be four characters or less. The owner name and member name must have been previously defined in a RECORD statement. No information concerning keys are available in the SET statement.

1.3.2.2 The Data Manipulation Language -

The data manipulation language (DML) for the prototype PDR consists of a series of memory resident subroutines to allow programmed manipulation of internal data stored in the relationships described by the currently loaded DDL. It is assumed that the reader is familiar with CODASYL database concepts.

The DML allows the programmer to maintain four types of currency pointers. They are as follows:

1. Current of set type
2. Current of member of set
3. Current of record type
4. Current of run unit

In order to trace through the database, the following DML routines are provided:

1. Set current of run unit based on current of set membership
2. Set current of run unit based on current of set type
3. Set current of set type based on current of run unit
4. Set current of set membership based on current of run unit
5. Set current of set based on current of set membership
6. Set current of set membership based on current of another set ownership

For database access of a record the following functions were written:

1. Find first member of a set
2. Find last member of a set
3. Find previous member of a set
4. Find next member of a set

Once the data record is located it can be pulled into the active data buffer and put into the LED display. After data modification occurs, the active data buffer can be stored back into the database. Constructs are developed for creating new data records and inserting them into the database. Low level functions of data modification, data translation and data display are developed. There are no constructs for deleting a data record. Thus, no "garbage collection" of the database is necessary.

1.3.2.2 Internal Data Structures -

With each record description in the DDL a template is constructed for the internal COSMAC DBMS routine system. This template contains information about the generalized structure of the stored data. The template takes the following form.

```
RTYPE (1 Byte) ........record type
TPTR (2 Bytes) ........text pointer
NSETS (1 Byte) ........number of sets
OSET1 (1 Byte) ........owner set 1
OSET2 (1 Byte) ........owner set 2
etc.                   remainder of owner sets
MSET 1 (1 Byte) .......member set 1
MSET 2 (1 Byte) .......member set 2
etc.                   remainder
EOL (1 Byte)   ........end of list = zero
NDATA (1 Byte) ........number of data bytes
NITEM (1 Byte) ........number of items
Item descriptions .....item descriptions
```

The actual data when stored in the DBMS took the following form.

RTYPE - record type
list of owner pointers 2 bytes each
list of member pointers 2 bytes each
4 byte old-new item descriptor (not used)
item data according to descriptors

The currency pointers take 4 bytes where the first 2 bytes have the address of the current record and the next 2 bytes point to the template, of the record.

The SETS template is less complex. It consists of a single table indexed by the set type. Each entry contains 2 bytes. The first byte is the record type of the owner. The second byte is the record type of the member. The last important data structure involved with the DBMS is the RECORDS data dictionary. For each record type there is an entry in a data dictionary (indexed by record type 1 containing the record name) containing the record type name. This dictionary is used for display purposes and inspector review.

1.3.3 Command Language Interface

The Command Language Interface (CLI) is the inspectors viewport into the DBMS of the PDR. The CLI should model the inspection procedures as closely as possible. The CLI should be easy to learn and easy to use. The CLI should allow the inspector to perform his tasks the way he is used to performing his tasks.

Although the prototype CLI did not achieve all of these goals to complete satisfaction, the CLI prototype chosen was a starting point to test the functional concepts of the PDR with respect to inspection procedures. The prototype CLI is designed with three basic modes of operation. These modes allow a user to use the PDR as a data terminal, a data base storage device and a data acquisition device.

1.3.3.1 Terminal Emulation -

When the PDR is first turned on, it initially emulates the function of a timesharing data terminal. At this point, the user has four options. The user may log onto a timeshare system, run the timeshare data base system (TDBS) and either down line load the PDR with a new data base or the user may send back to the TDBS an already existing database in the PDR. The third option available is to enter tape command mode (TCM). The fourth option is to shut off the PDR.

The following is a list of terminal commands.

1. LOGON - log onto the system and activate TDBS
2. LOGOFF - close TDBS and log off
3. SAVE - save COSMAC data base into TDBS
4. LOAD - load COSMAC database from TDBS
5. TAPE - go to tape mode
6. SEND - send current line typed to TDBS
7. <- - scroll left
8. > - scroll right
9. START - go to beginning of display
10. END - go to end of display

If LOGON is unsuccessful after 5 seconds, an error message will result and the command must be reissued. LOGOFF, SAVE, LOAD, and SEND will not work if LOGON has not been completed. TAPE command will cause an automatic LOGOFF.

1.3.3.2 Tape Command Mode (TCM) -

From TCM the user may access the tape drive to load and store the data base on cassette tape. In addition, the user may return to terminal emulation or shut off the PDR. The final option available is to enter database access mode. The following is a list of TCM commands.

1. ESCAPE - return to terminal emulation
2. SHUTDOWN - turn off the PDR
3. SAVE - save the data base on to the tape
4. LOAD - load the data base from the cassette
5. DATA - go to database access mode
6. PLAYBACK - playback the cassette tape vocal records

1.3.3.3 Data Base Access Mode (DBAM) -

DBAM is the basic system mode by which a user may examine and modify various portions of the PDR dara base. When DBAM is entered, the PDR will immediately search for the identification information associated with the COMPLEX for this data base. If no information is found, an error message is displayed and terminal emulation mode is to be re-entered.

The data is structured in a semi-hierarchical fashion. The user must search down the hierarchy to access the data that needs to be examined or modified. For example, when DBAM is initially entered, the display will be showing information about the current COMPLEX. The top display will have field identification information, and the bottom display will have the current data associated with the particular field.

One character in the top display will be blinking, as an indicator for the user as to where data entry and modification will occur. The user may move the display to the left or to the right or to the beginning of the display or to the end of the display with a single key stroke.

If the user wishes to know what information can be accessed at the next level in the data hierarchy, a command is issued and a table of contents will appear showing what data can be accessed. For example, from the COMPLEX record, the user would see the following type of information upon request of the table of contents.

1-SUMMARY 2-ENFORCE 3-STRUCTURE, etc.

To find the STRUCTURE record, the user would enter the command FIND 3. The PDR would find the data associated with the first STRUCTURE associated with the COMPLEX. If there was more than one STRUCTURE, the user could issue the NEXT command and the PDR would find the next STRUCTURE in the system.

Note that each time the user changes records, the current record if modified will be resaved in the data base and the old information for that record will be lost. If the user wishes to restore the old contents if must be requested explicitly before changing records.

The following is a list of DBAM commands.

1. ESCAPE - return to TCM mode
2. TOP - find COMPLEX record (go to TOP of hierarchy)
3. VOICE - enter a vocal record and associate it with current record in the display
4. < - move display window to the left
5. > - move display window to the right
6. CTRL < - move to beginning of display
7. CTRL > -move to end of display
8. OLD - show old record contents
9. NEW - show new record contents
10. RESTORE - return original contents of the record
11. TOC - display table of contents of record types that can be accessed next
12. FIND i-find a different record type. Identified by i (i is index)
13. NEXT - find next record of the current type being displayed
14. PREVIOUS - find previous record of the current type being displayed
15. FIRST - find first record of the current type being displayed
16. LAST - find last record of the current type being displayed (value displayed in table of contents)
17. ADD - add a record of the current type to the data base. Note that the record initially contains no information.
18. NEXTFLD - go to next field in record
19. PREVFLD - go to previous field in record
20. CHECK - check off field as having been looked at
21. TYPE - the name of the current record type will be displayed

PDR KEYBOARD PRELIMINARY LAYOUT

TOP ROW IS WITH CONTROL KEY
BOTTOM ROW IS WITHOUT CONTROL KEY

	1	2	3	4	5
8	. 1	+ 2	- 3	4	5
7	DATA 6	TAPE 7	TERM 8	LOGON 9	LOGOFF 0
6	SEND A	ABORT B	C	SAVE D	LOAD E
5	OLD F	NEW G	RESTORE H	CHECK I	J
4	FIRST K	LAST L	NEXT M	PREVIOUS N	ADD O
3	P	TOC Q	FIND R	S	T
2	U	V	W	X	Y
1	CONTROL	PLAYBACK VOICE	START LEFT	END RITE	SHUTDOWN Z

1.3.4 Communication Interface

The data communications protocol used for loading the PDR follows the same format as described earlier. Data is sent in variable length records from the PDP 11/45 with a maximum length of 255 bytes. Each record begins with a STX byte followed by the record length. Data bytes follow and then an 8 bit checksum. If checksums do not agree, a NAK is sent and the PDP 11/45 will retransmit the data record. If four consecutive NAK's are issued the loading procedure is aborted and an error message is displayed in the LED display. The last message sent by the PDP 11/45 is always ETX.

Transmission back to the PDP11 takes a slightly modified form. All data is repacked so that every 6 bits of data are sent in an eight bit byte with the high 2 bits set to 1. This insures that all data sent out of the PDR is in the printable ASCII range. This insurance provides for easier transportability for input to other machine operating systems for future modifications.

1.4.0 Prototype Evaluation

The prototype software developed for the PDR, although not totally completed, verified the possibilities of building a generalized database management system on a primitive processing device. The software suffered from two major hardware problems. First, there was insufficient memory available on the prototype hardware configuration, and secondly the primitive processor instruction set impeded faster software development.

The first of these obstacles can obviously be overcome by adding more memory. Data base management usually implies that a significant amount of data is to be manipulated. Traditionally, these large amounts of data are stored on a medium speed rotating memory. This type of storage is not possible in a hand held configuration. An alternative media to fast random access memory would be a fast sequential access memory (e.g., bubble memory). This replacement would allow higher densities of data storage at a lower cost. New software algorithms would have to be designed to exploit the sequential nature of the memory. Ideally the sequential memory should be non-volatile, like a cassette tape or rotating disc.

Another area requiring more research is the area of data compression techniques. Since a large portion of the stored data is in textual form, new methods for compressing stored data would reduce the memory requirements. No research was done in this area for the first software prototype.

The second of the prementioned obstacles can be overcome by selecting a different processor. At the time this project was initiated, the RCA processor was the only low power processor which was commercially available. The market now offers other processors with low power requirements, but more advanced instructions sets. These new processors also contain better machine architectures and improved program development facilities. With better program development facilities and more powerful machine architectures the software effort can be significantly reduced.

Software developed for general I/O support can be reduced by using more intelligent peripheral devices. Displays should be configured with local intelligence to absorb many of the functions designed in the prototype software. Keyboards should have the capability of "self-validation" and "self-code generation" to remove the burden from the PDR main processor. In order to facilitate faster access, the tape drive should contain a fast random access mode. In this manner, the inspector may locate verbal comments quickly when required.

The data base management facility developed is only a first effort. As the processors become more powerful, the data management capability can be increased without loss of processing time. The DDL cross-compiler concept allows the generation of new data management tables for different target processors. With more advanced hardware, the software prototypes can be made into a realizable system.

CHAPTER 2. HARDWARE DESIGN OF THE PORTABLE DATA RECORDER

The design is based upon the use of a microprocessor. This type of design lends itself to many diverse applications, where only changes in software would be required to implement specific capabilities within the existing hardware design. As shown in figure 7, the major components of the PDR include.

(a) microprocessor,
(b) memory,
(c) keyboard,
(d) tape deck,
(e) alphanumeric display, and
(f) power supply.

Sections 2.1 through 2.6 and the schematics discuss the original design which was done in the last half of 1977. Since the original design, advances in the state of the art have made new electronics available, these will be discussed in section 2.7.

2.1 Microprocessor

The PDR uses an RCA 1802 COSMAC microprocessor. This 8-bit complementary metal-oxide semiconductor (CMOS) integrated circuit (see fig. 8) was chosen because of the low power consumption and high noise immunity of CMOS devices and because of its convenient word size bit (8 bits). The microprocessor communicates with other devices through an 8-bit bidirectional data bus and 15 input/output control lines. Memory addressing is through a multiplexed 8-bit address bus sensing of four lines, direct control of a single line, interrupt and direct memory access (DMA) capability.

2.2 Memory

The PDR contains 2048 bytes of ROM and 2048 bytes of (read/write) RAM. The system (see Fig. 9) is designed to allow the use of either the RCA CDP1832 mask programmable ROM or the industry-type 2704/8704 electrically reprogrammable ROM. RAM comprises an RCA CDP1822 256 x 4 bit static memory. If needed, memory expansion is straightforward.

2.3 Keyboard

The system used a 5 x 8 matrix keyboard with momentary switch closures. To determine if a switch has been depressed, the microprocessor program scans the keyboard. This is accomplished by setting one of the five output bits to the keyboard low (see keyboard schematic in fig. 10) and then reading in the state of the eight keyboard input lines. If a switch is depressed, the low output line is connected to one of the input lines, and the input line is pulled low. By sequencing through each of the five output lines one at a time, a depressed key can be sensed and decoded.

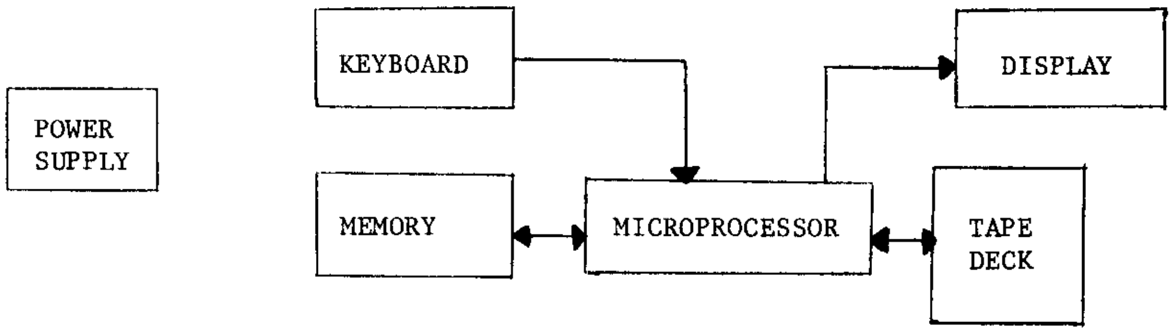

Figure 7. Block diagram of portable data recorder.

2.4 Tape Deck

The tape deck circuits in the system (see Figs. 11a and 11b) can record and play back both analog (voice) and digital information. This is implemented by using a Triple I cassette deck which records two tracks of information on a standard Phillips-type audio cassette. One track contains verbal information and the other digital dates. The digital system would store data on the tape using two different frequencies to represent the two binary states. The technique used[2] was selected because of its self-clocking and therefore tape-speed-tolerance feature. The data are stored in a bit serial fashion in records of arbitrary but known length. The voice-recording capability dictates the use of at least one track of analog recording; cost then dictates that the other track be analog as well.

2.5 Alphanumeric Display

The original system design called for Hewlett-Packard HDSD-2000 alphanumeric light-emitting diodes (LED's) for the display elements. Since the original design, Litton has come out with a display element which is cheaper and easier to use, the Litronix DL-1416. This integrated circuit is treated as memory and, therefore, each character is written into the appropriate space using its standard ASCII (American Standard Code for Information Interchange) code (see Fig. 12). This is a big improvement over the HP chip since much of the complicated interface circuitry is eliminated.

An LED display was chosen over a liquid-crystal display for several reasons. These include

(a) availability,
(b) cost, and
(c) circuit simplification

Liquid-crystal displays do have some advantages, such as low power requirements and good visibility in high ambient light conditions, and if necessary, the display can be changed.

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[2] Don Lancaster, Build the Bit Boffer, Byte Magazine (March 1976).

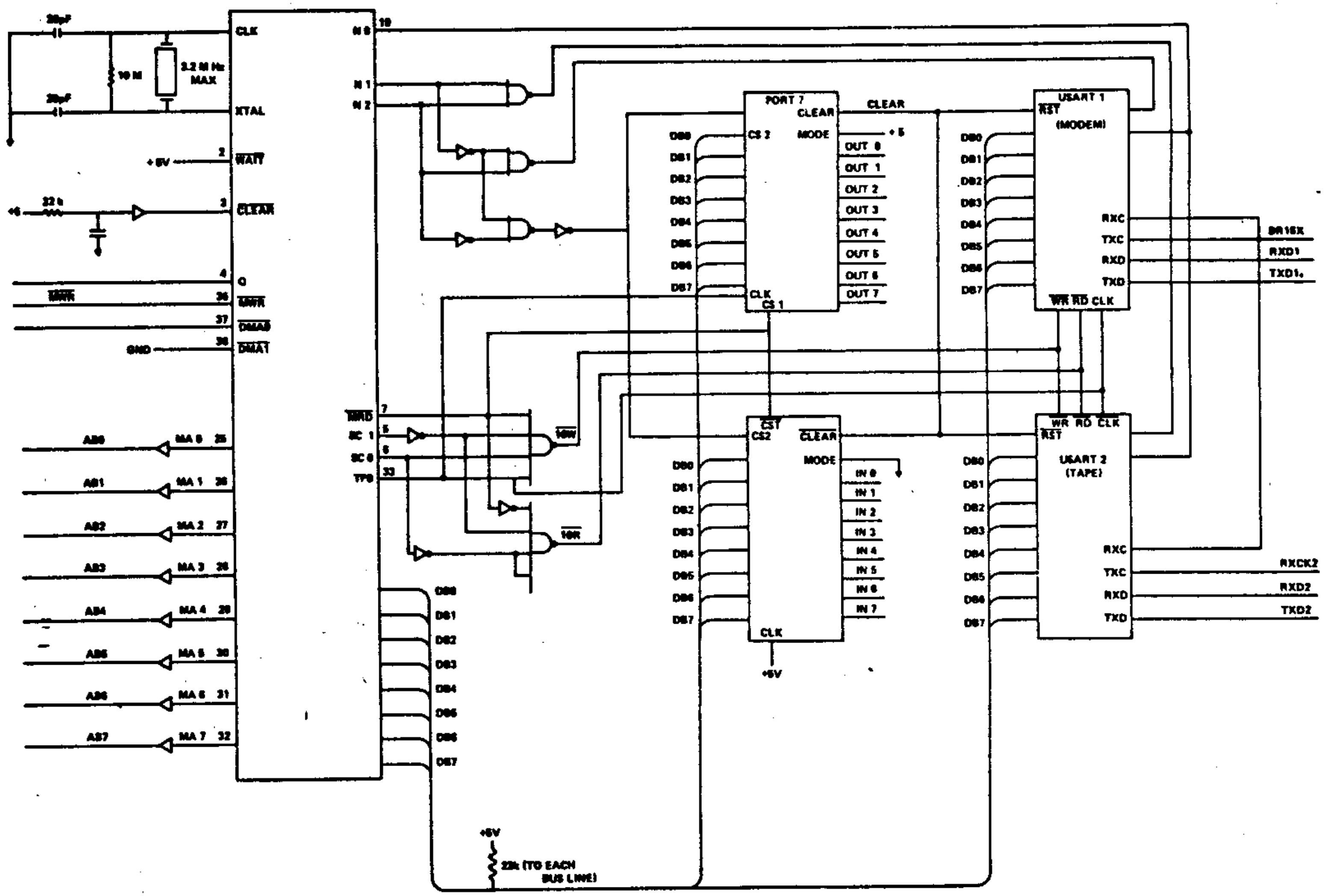


Figure 8. Schematic of COSMAC microprocessor system.

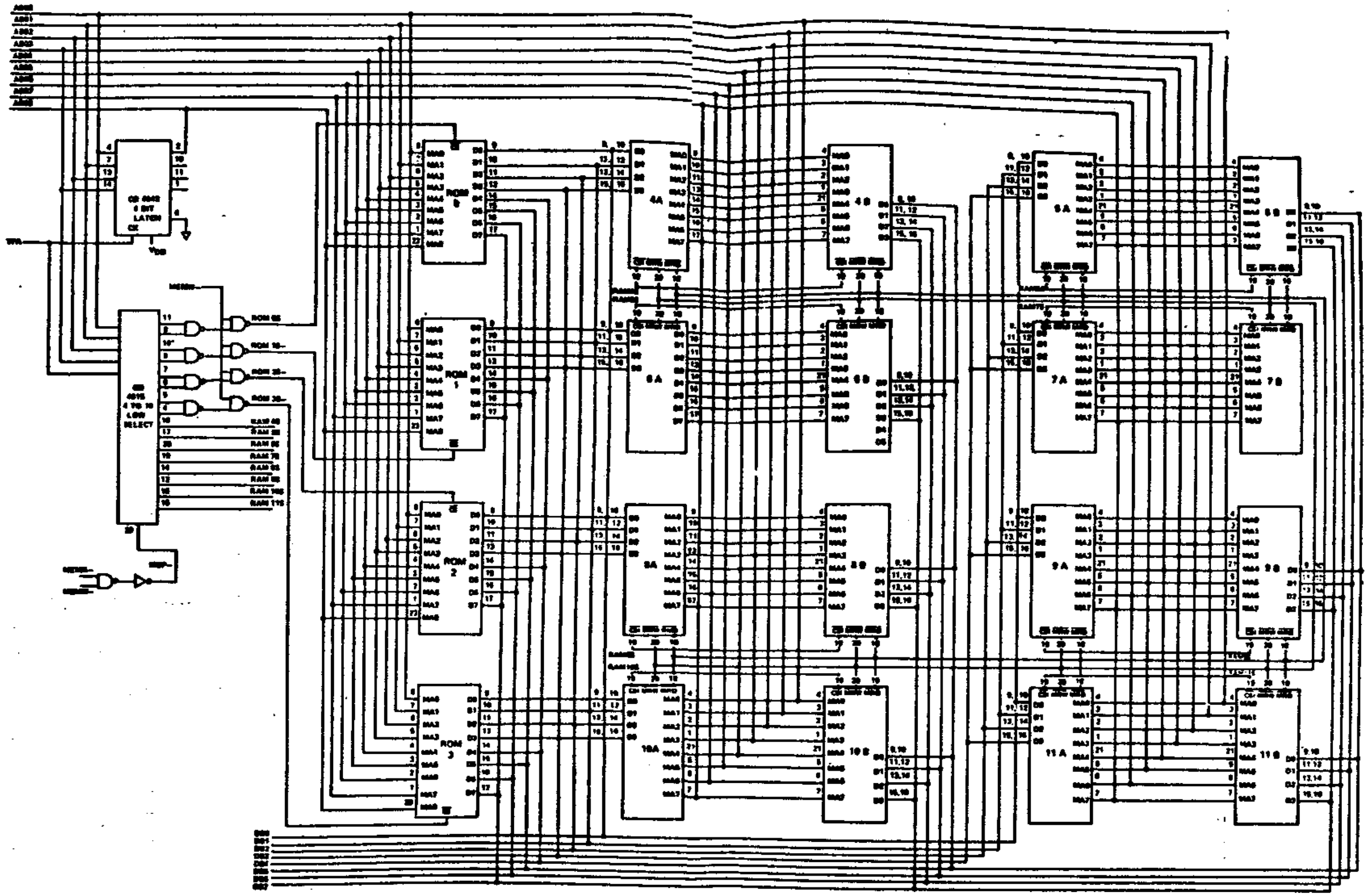


Figure 9. Schematic of COSMAC memory.

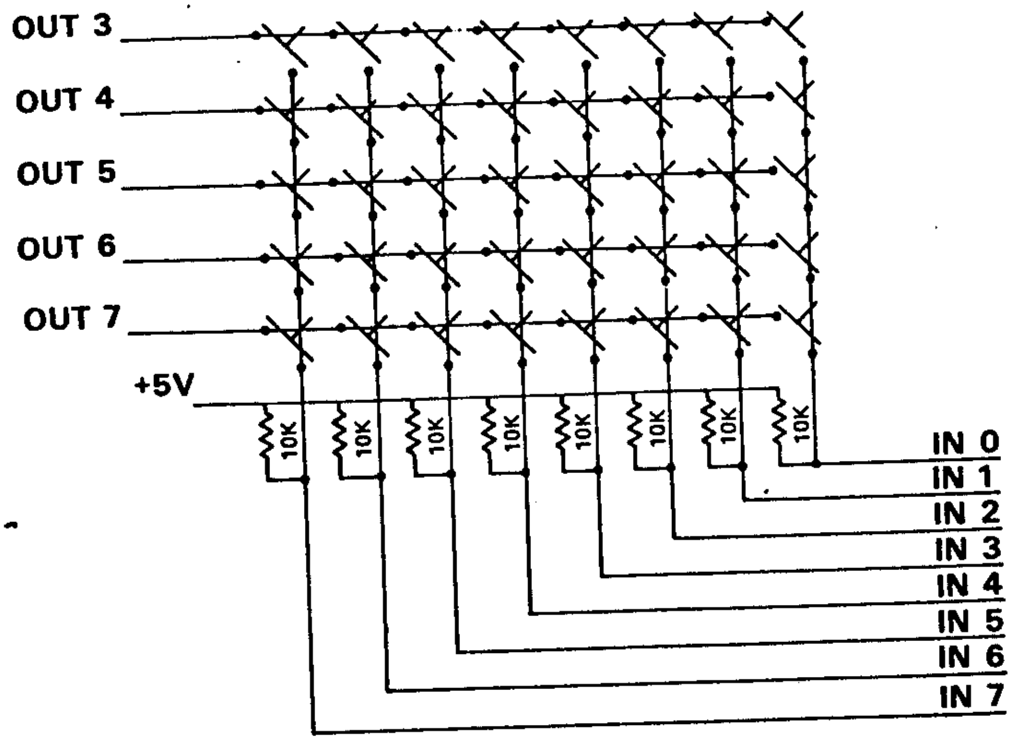


Figure 10. Schematic of keyboard and interface.

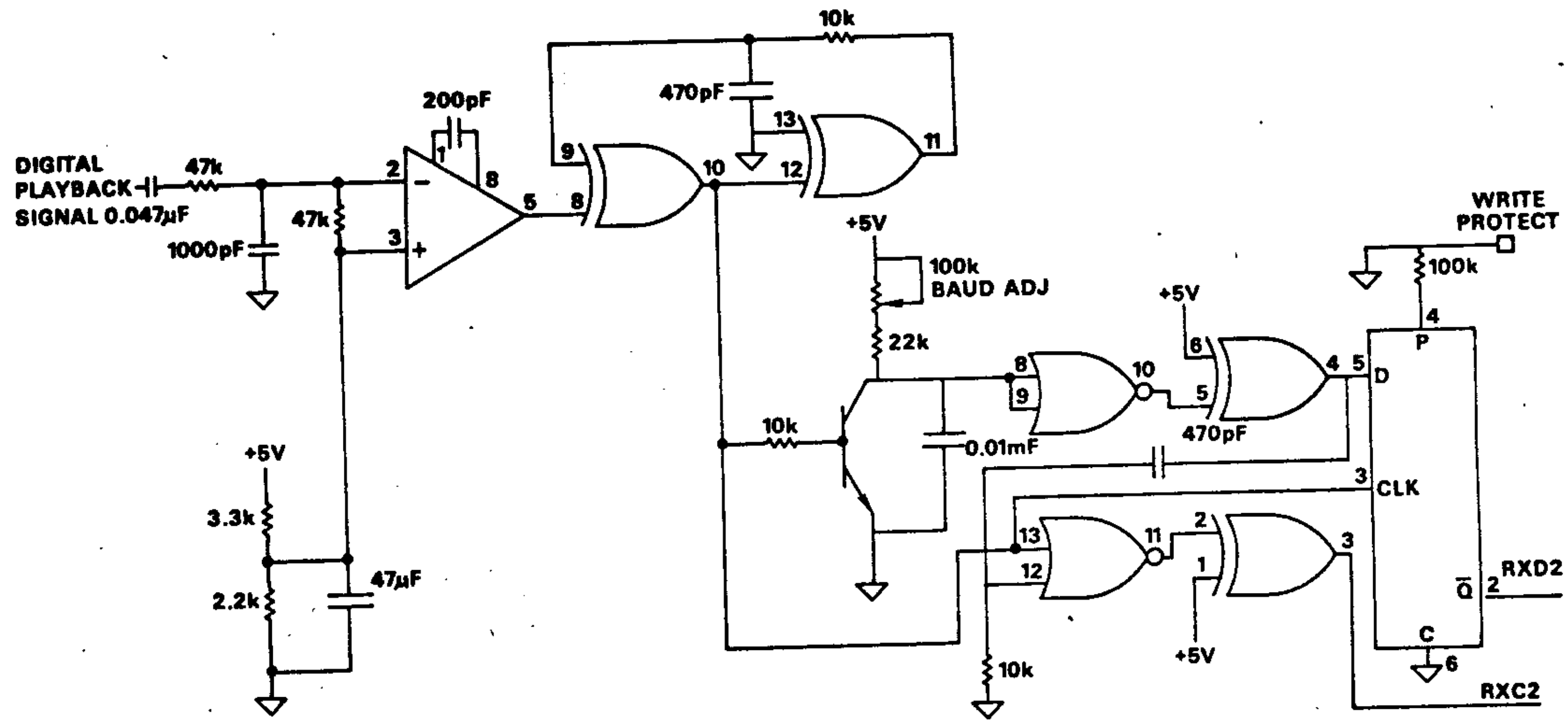


Figure 11(a). Schematic of tape deck read circuit.

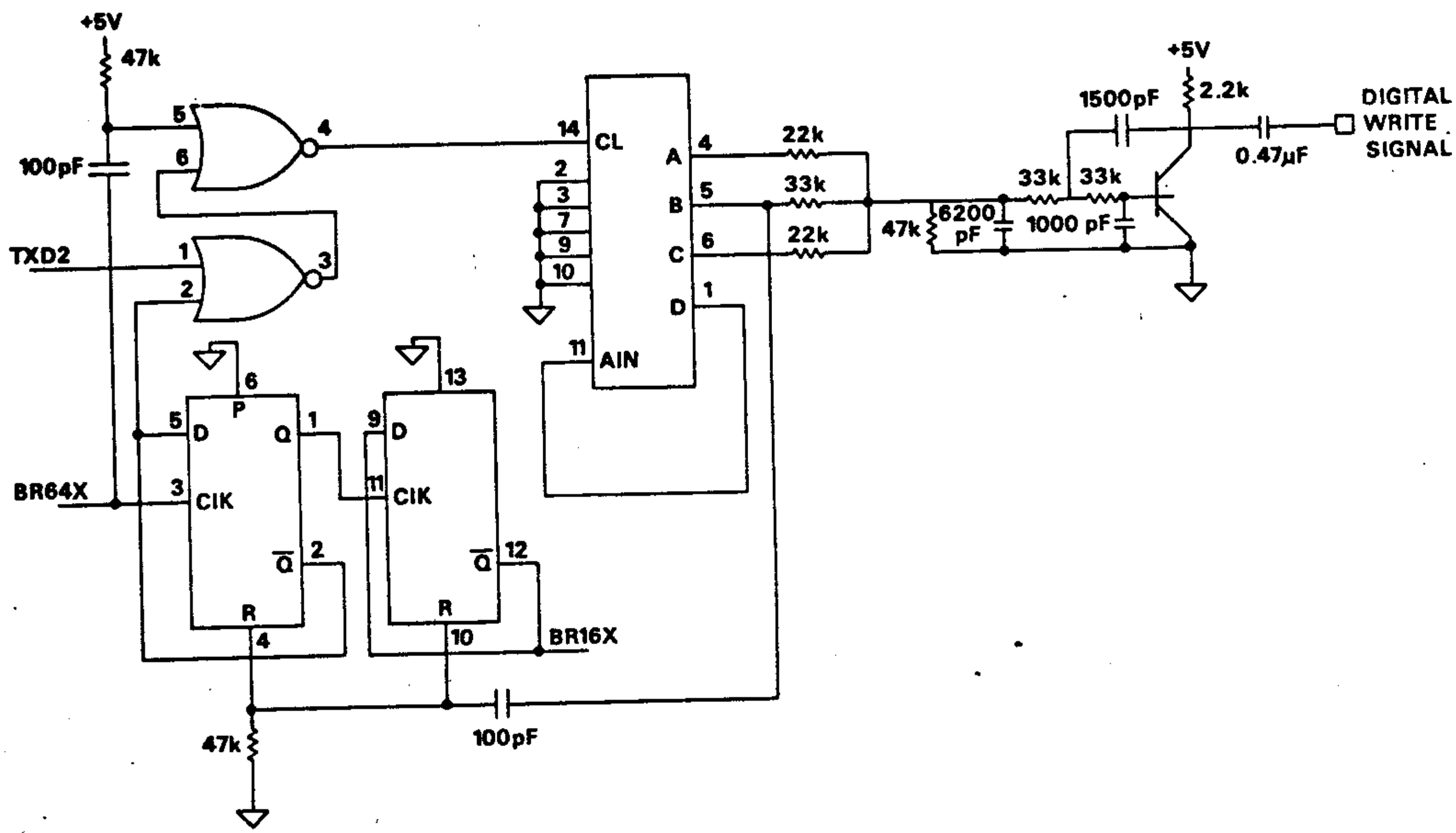


Figure11(b). Schematic of tape deck write circuit.

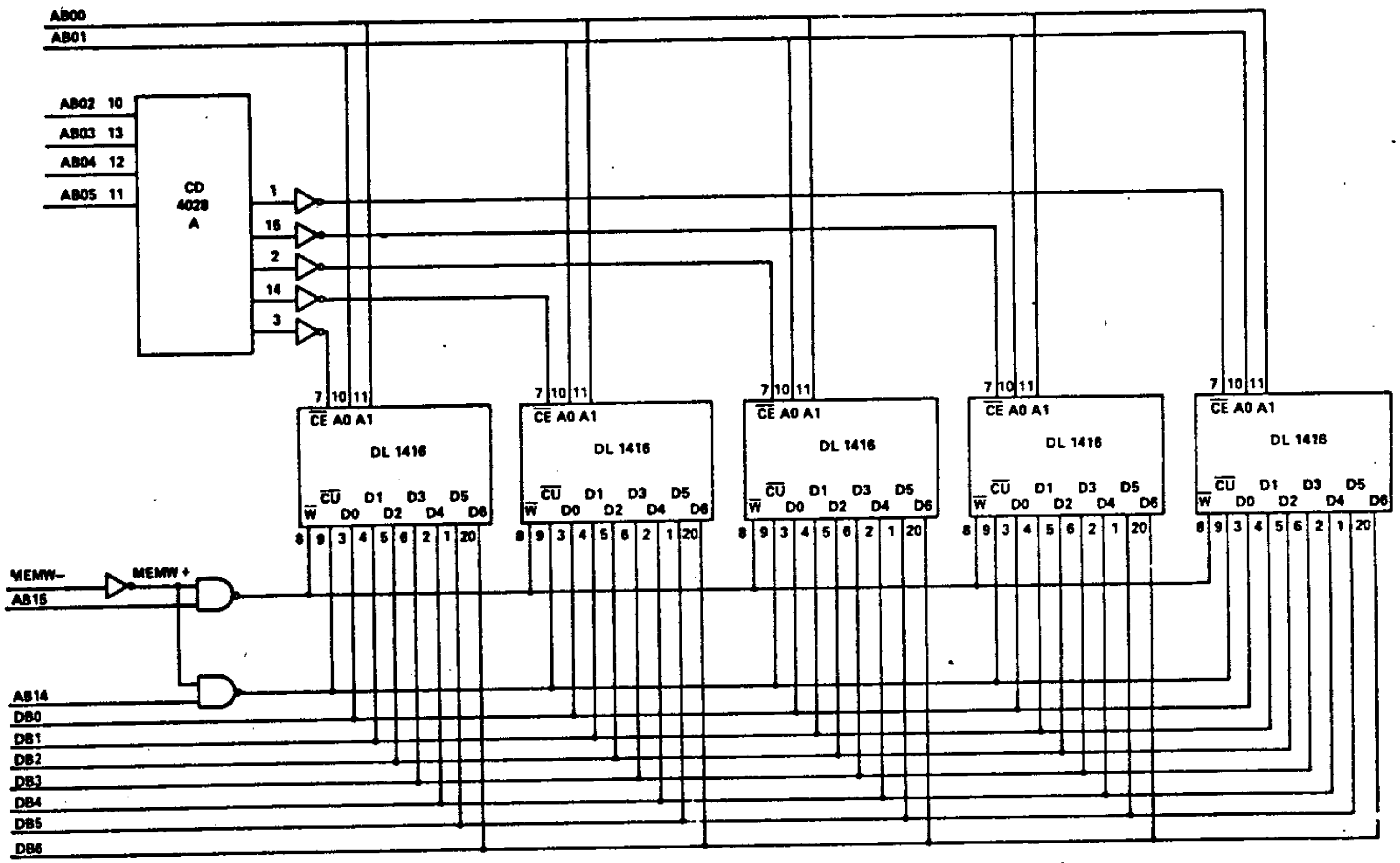


Figure 12. Schematic of alphanumeric display circuit.

2.6 Power Supply

The power supply will be a standard nickel-cadmium battery pack.

2.7 Partial implementation of the Portable Data Recorder System and further analysis of the requirements and operator interface revealed weaknesses in the original design. A discussion of the hardware weaknesses follows.

2.7.1 Microprocessor - The COSMAC is a very limited microprocessor which lends itself more towards simple hardware control rather than a large data base management problem as we have here. It became evident that a more powerful micro was needed to control the system. The Rockwell 6502 (and others) could better meet the system requirements at a cost of more power consumption. It is expected though a similar device will be available with lower power requirements in the near future.

2.7.2 Memory - To make the data recorder usable in essentially random sequence of data collection, the data base must be stored in a non-volatile, random access memory. The original plan was to store the data on tape in an audio format. As the amount of data increased, access time to the data also increased making tape storage in an audio format undesirable. Recent advances in commercially available bubble memories and support circuitry make bubble memories a logical choice for the majority of the memory. This would allow the use of a simple dictating tape recorder for verbal comments.

2.7.3 Display - It was determined that a forty character display was insufficient for efficient communication between the recorder and operator. One solution to this problem is to use a liquid crystal display with more characters. A prototype would have to be tested to assure adequate service life under the humid conditions found on oil platforms and rigs. Large scale integrated circuits have relieved some of the burden on required drive circuitry since the original design of the recorder.

3. Conclusions - Rapid advances in the availability of microprocessors, bubble memories and displays, coupled with the increased system requirement makes redesign of certain system blocks in the data recorder highly desirable. Design goals are within the microelectronic state-of-the-art. However, achieving them at a price below $1,000 is still unobtainable. A firm estimate of the cost and size of the finished item would require the redesign to be completed, but it is not unreasonable to expect the cost of this type device to be over $2,000 each (not including the cost of the redesign). The weight should be less than 3 kg. This is confirmed by literature from Electro/General Corp. which manufactures a portable data recorder (lacking data base management capability) which sells for $2,590.

Chapter 3 - Human Factors Evaluation of the Portable Data Recorder Concept

A report, submitted by the U.S. Army Research Institute and included as Appendix B has as its conclusion that the USGS should not pursue the portable data recorder because:

a) the present system works good enough
b) the portable data recorder would not work much better.

This position conflicts with the belief of inspectors and supervisors at the time that this research was started. This position can be attributed to an attitude by inspectors that "We can do our job!". This attitude has been fostered, at least in part, by prolonged attacks from the media and politicians seeking to find fault in civil service employees upon which some element of blame for the energy crisis can be placed. Such an attitude tends to defeat attempts to make the job easier or to improve the performance. Thus, such an attitude would cause rejection of changes such as this data recorder. Regretfully, we must concur with ARI.

Summary

The concept of a portable data recorder meeting the needs of USGS inspectors in OCS Oil and Gas Operations was defined and examined in detail. Software was created and implemented on a low current drain microprocessor to demonstrate technical feasibility. A subsequent human factors study then revealed that a recorder having the necessary complexity was unlikely to be more practical than the present manual transcribing methods. This research, having determined feasibility without advantage, was therefore terminated.

Conclusion:

The portable data recorder is technologically feasible. However, for cost and human factors, it cannot substantially improve cost or performance of inspections and record keeping at this time. The use of a commercial CRT terminal to permit on-line operation in an interactive query/retrieval system is considered to be a superior alternative.

Recommendation:

This research should be terminated, and the data recorder reconsidered in 1981 because cost of components is expected to be drastically reduced by then. It should then be pursued by USGS inspection personnel working with a vendor such as Electro-General (see Appendix C). The use of an interactive terminal, on-line, using the database computer in a time-share mode via telephone should also be considered.

APPENDIX A

THREE EXAMPLES OF INSPECTOR DATA FORMS

DISTRICT _ COMPLEX ____

DATE THIS INSP __/__/__

U. S. GEOLOGICAL SURVEY
PLATFORM INSPECTION SYSTEM
COMPLEX INITIALIZATION

PAGE NO. __

COMPLEX ID	AREA	BLOCK	LEASE	FIELD	LEASE OPERATOR	CO. REPRESENTATIVE
____	__	____	___	____	______________	______________

** TIME SUMMARY **

		CURRENT
INSPECTION		__.__ HR
WAITING		__.__ HR
TRAVEL		__.__ HR
TOTAL	HR	__.__ HR

TYPE INSPECTION CURRENT __

INSPECTORS CODE CURRENT	INSPECTOR'S SIGNATURE
__	______________
__	______________
__	______________
__	______________

*** ENFORCEMENT ACTION ***

LINE NO.	STR NO.	WELL NUMBER OR ITEM NAME	ENFORC ACTION	INC NO.	*---SHUT-IN---* DATE MO/DA/YR	TIME HR	*--REOPENED--* DATE MO/DA/YR	TIME HR	COMMENTS	LOST PROD. OIL BARRELS	GAS MCF	AVG. DAILY PROD. OIL BARRELS	GAS MCF
01	__	______________	____	___.__	__/__/__	__.__	__/__/__	__.__	______________	____	____	____	____
02	__	______________	____	___.__	__/__/__	__.__	__/__/__	__.__	______________	____	____	____	____
03	__	______________	____	___.__	__/__/__	__.__	__/__/__	__.__	______________	____	____	____	____
04	__	______________	____	___.__	__/__/__	__.__	__/__/__	__.__	______________	____	____	____	____
05	__	______________	____	___.__	__/__/__	__.__	__/__/__	__.__	______________	____	____	____	____
06	__	______________	____	___.__	__/__/__	__.__	__/__/__	__.__	______________	____	____	____	____
07	__	______________	____	___.__	__/__/__	__.__	__/__/__	__.__	______________	____	____	____	____
08	__	______________	____	___.__	__/__/__	__.__	__/__/__	__.__	______________	____	____	____	____
09	__	______________	____	___.__	__/__/__	__.__	__/__/__	__.__	______________	____	____	____	____
10	__	______________	____	___.__	__/__/__	__.__	__/__/__	__.__	______________	____	____	____	____
11	__	______________	____	___.__	__/__/__	__.__	__/__/__	__.__	______________	____	____	____	____

DISTRICT _ COMPLEX ____

DATE THIS INSP __/__/__

U.S. GEOLOGICAL SURVEY
PLATFORM INSPECTION SYSTEM
COMPLEX INITIALIZATION

PAGE NO. __

	COMPLEX-ID	AREA	BLOCK	LEASE	FIELD	MANNED(24HRS)
NEW	____	__	____	____	____	_

	--------LEASE OPERATOR---------- CODE	NAME	MILES TO SHORE	WATER DEPTH	DATE OF FIRST PRODUCTION
NEW	__	________________	__	___	__/__/__

	STRUCTURE ID USGS	CO. NAME	NO. DECKS	NO. SLOTS	SLOTS DRILLED	MAJOR	*COMPLETIONS* U/WTR	SAT	YEAR INST	YEAR REMOVED
NEW	__	______	_	__	__	_	__	__	__	__
NEW	__	______	_	__	__	_	__	__	__	__
NEW	__	______	_	__	__	_	__	__	__	__
NEW	__	______	_	__	__	_	__	__	__	__
NEW	__	______	_	__	__	_	__	__	__	__
NEW	__	______	_	__	__	_	__	__	__	__
NEW	__	______	_	__	__	_	__	__	__	__

	CURRENT
COMPLEX STATUS:	
ABANDONED	_
DRILLING	_
PRODUCTION	_
WORKOVER	_
MAJOR COMPLEX	_
GENERAL:	
HELIPORT	_
ATTENDED(8HRS)	_
PRODUCTION EQUIPMENT	_
COMPRESSOR	_
FIRED VESSEL	_
QUARTERS(#BEDS)	___
POWER GENERATION	_
STORAGE TANKS	_
TYPE PRODUCTION:	
GAS	_
OIL	_
WATER	_
CONDENSATE	_
METERING:	
SALES,GAS	_
ALLOCATION	_
LACT	_
TANK GAUGE	_
GAS FLARING	_

COMPLEX SUMMARY *------ZONES------*	CURRENT
PRODUCING OIL	__
GAS LIFT OIL	__
PRODUCING GAS	__
SHUT-IN OIL	__
SHUT-IN GAS	__
TEMPORARY ABANDON	__
PLUG & ABANDON	__
GAS INJECTED	__
WATER INJECTED	__
WATER SOURCE	__
WATER DISPOSAL	__
UNPERFORATED	__
FIELD SERVICE	__
PARALLEL TBG STRING	__

DISTRICT _ COMPLEX ____

DATE THIS INSP __/__/__

U . S . G E O L O G I C A L S U R V E Y
P L A T F O R M I N S P E C T I O N S Y S T E M
C O M P L E X I N I T I A L I Z A T I O N

WELL BAY AND FIELD RECORDS

LINE NO.	STRUC NO.	WELL ID	ZONE STAT	SGN Y/N	NO. MAS VAL	WP TREE PSI	WP HEADER	PSV	TBG PRESS PSI SI	TBG PRESS PSI FLO	PROD CSG. PSI	*FLOWLINE* *-RANGE-* HIGH	*FLOWLINE* *-RANGE-* LOW	*SENSOR-* *-TEST--* PSH	*SENSOR-* *-TEST--* PSL	SSV TST H/L	2ND VAL Y/N	FSV H/L	TSE Y/N	*---SUBSURFACE SAFETY DEVICE-----> TBG INST 12/72	SUR-FACE CNTL	MAKE MOD TYPE	DPTH SET	DATE PEN/INSP	LAND NIP Y/N	FLO CUP Y/N

APPENDIX B

FORWARD

This report is the product of a Harry Diamond Laboratories (HDL) request for human factors technical advisory service. This report discusses the Portable Data Recorder (PDR) concept in terms of human factors, behaviorial, and system considerations.

Information for this report was compiled by U.S. Army Research Institute (ARI) personnel from visits to HDL (Adelphi, Maryland), U.S. Geological Survey (USGS) Headquarters (Reston, Virginia), and USGS, Metarie District (New Orleans, Louisiana). The last location mentioned involved a one day visit to several offshore oil platforms in the Gulf of Mexico.

The report is divided into five sections: a brief description of PDR concept/device and of the current data collection/processing system; analysis of the data collection/processing system; evaluation of the PDR concept; recommendations for the USGS data collection/processing system; and a summary of the report.

COMMENTS ON THE PORTABLE DATA RECORDER CONCEPT
PROPOSED FOR U.S. GEOLOGICAL SURVEY

1. INTRODUCTION

A. The Current Data Collection/Processing System and the Portable Data Recorder (PDR) Concept.*

The sequence of operations currently required to get operational data, collected by the field inspector, into the USGS computer data base is very complex. The current data collection/processing system is depicted in Figure 1. It describes the major events that are of interest in this report. Note that the figure shows three sources of human error: inspector data entry; transcription of inspector to keypunch forms; and, transcription of keypunch form entries to computer cards.

The following is a detailed explanation of each of the seven steps shown in Figure 1:

(1) Inspection Forms Are Prepared And Sent To Field Inspectors.

Based upon data resident in the USGS computer data bank, inspection forms are printed for use by the field inspectors during the inspection of a particular offshore structure (Appendix A contains sample forms). Space is provided on the forms for the inspector to enter current data values as well as any appropriate comments he might have.

(2) Inspectors Enter Data And Comments On Forms During Inspection Of Platform.

A team of inspectors are scheduled to inspect particular offshore facilities over a one to three day period, depending upon the size of the facility and the type of inspection scheduled. The ensuing inspection then takes place in three phases.

In the first phase, the inspectors are provided with records of the inspection data collected by the company since the last USGS visit. These data are evaluated and the appropriate values are entered onto the USGS inspection forms. An Incidence of Non-Compliance (INC) is issued if the proper tests were not conducted by the operator or if the test data indicated an unsafe condition for which the required corrective action had not been taken.

*This section was extracted almost entirely from an HDL report describing the PDR concept and prototype device.

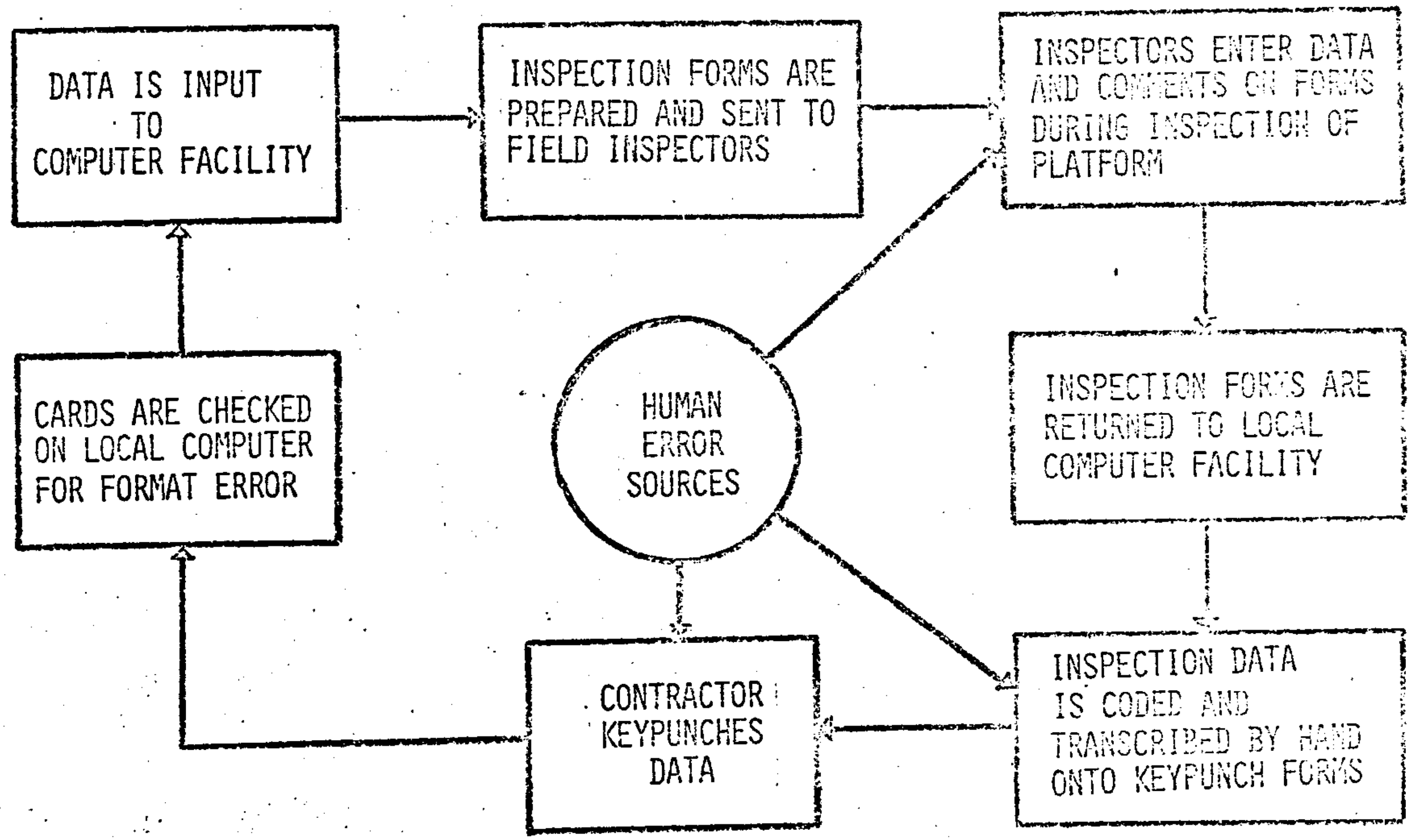


FIGURE 1. OVERVIEW OF THE CURRENT USGS DATA COLLECTION/PROCESSING SYSTEM

While one inspector is reviewing the company records, the other member of the team makes a visual inspection of the platform. As part of the second phase, he fills in that part of the inspection form dealing with such safety items as potential fire hazards (improperly stored flammable materials, improperly deplyed or maintained fire-fighting equipment), personnel safety items (holes in the deck, cluttered walkways, missing or loose stair railings) and maintenance of signs identifying the structure, its operator and location. If the operator is found to be delinquent in any of these areas, he is issued an appropriate INC.

The thrid phase of the inspection calls for the USGS teams to witness the testing of certain equipment by operator personnel. The results of these tests are recorded on the inspection forms and evaluated to see that the equipment performance complies with the USGS regulations.

In addition to recording the results of the test and inspection of individual items, before the inspection forms are turned in to USGS, the inspector must provide a summary of certain information. This includes such things as the number of items of a certain type that were inspected, the number that passed inspection, and the number that failed.

(3) Inspection Forms Are Returned To Local Computer Facility.

Once the inspection forms are completed by the field inspector, they are returned to the district office for subsequent entry into the computer data bank. This involves a physical transfer of the forms by means of a special messenger or the U.S. Postal Service.

(4) Inspection Data Is Coded And Transcribed By Hand Onto Keypunch Forms.

All inspection forms received by the district offices are reviewed and the data entered by the inspectors is recorded and transcribed onto keypunch-formatted forms. The code used is compatible with the data input format requirements of the USGS data base system. This entire step is of necessity done by hand.

(5) Contractor Keypunches Data.

Once the keypunch forms are completed, they are sent to a contractor who generates punched cards based on those forms. These cards and the forms are returned to the USGS district office.

(6) Cards Are Checked On Local Computer For Format Errors.

Upon receipt of the punched cards from the contractor, the cards are red by a computer in the district office. The computer is programmed to check for format errors in the punched cards. Any format errors that are detected are corrected by repunching the appropriate cards.

(7) Data Is Input To Computer Facility.

Once all detected format errors have been corrected, the data contained on the punched cards is entered into the USGS data base. There it will eventually be used to provide a basis for the printing of the inspection forms required for the next inspection of that particular offshore facility.

There seems to be some concern that the system described above is unwieldy and prone to frequent and/or serious human errors. A proposed remedy involves the use of a PDR (or PDR-type) device which would aid the inspector and enhance data processing.

B. The Basic PDR Procedures and Concepts

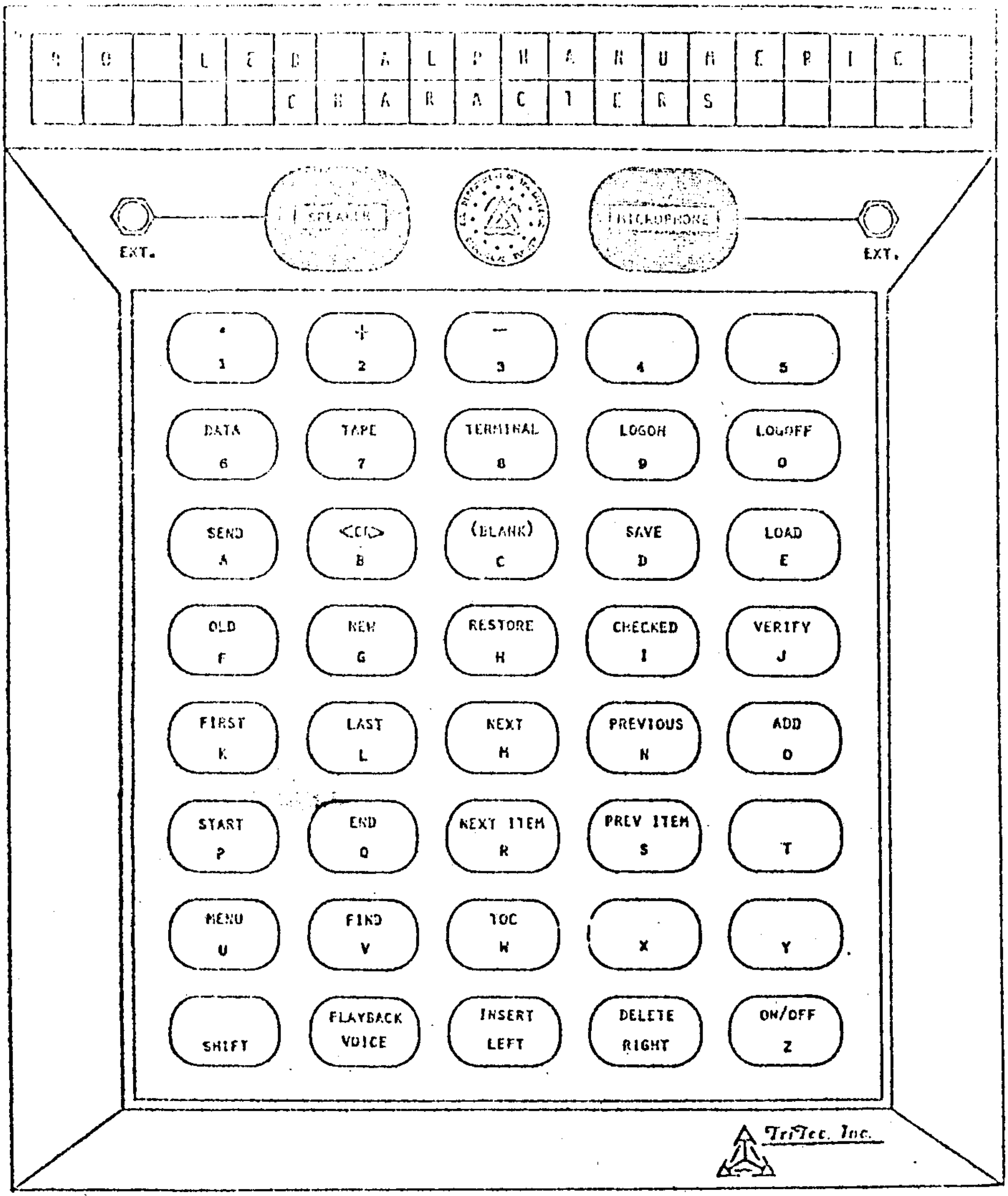
Briefly the PDR device would prompt the inspector for data input items via an LED display and the inspector would then make entries via the PDR keyboard which would appear on the LED display (See Figure 2 for a prototype PDR device). The PDR concept also takes into account inspector verbal comments by providing an audio-tape recorder capability. In addition, the PDR device would check the digital input data for format errors and send feedback to the inspcetor. The altered data collection/processing system would resemble that depicted in Figure 3. This figure differs from Figure 1 in several ways. Although human error still would be possible during inspector data entry, it supposedly would be less frequent and/or serious. With a PDR device there would be no need to transcribe inspector data since the computer would perform this task. Finally, the amount of key punching would be restricted to inspectors' verbal comments.

2. ANALYSIS OF DATA COLLECTION/PROCESSING SYSTEM

A. General Equipment Characteristics

(1) Diversity of Equipment and Equipment Configuration.

A visitor to several oil platforms quickly becomes aware of a myriad of equipment types and equipment configureations. (Major factors contributing to equipment diversification seem to be the types of oil platforms, the multitude of lessors, the many different types of equipment and the proliferation of equipment vendors.) Obviously equipment differs depending on the type of oil platform (e.g., drilling rigs, production complexes/structures, etc.). However, even at platforms of the same type, there is an overwhelming amount of equipment (e.g., pipeline systems, including pipeline sensors and pumps, pressure gauges and sensors, power generation devices, storage facilities and monitors, etc.). The equipment is purchased by different lessors from different vendors and configured in different ways.



NOTE: TOP DESIGNATION ON EACH BUTTON IS USED WHEN SHIFT BUTTON IS DEPRESSED; BOTTOM DESIGNATION IS FOR USE WITHOUT SHIFT BUTTON.

FIGURE 2. LAYOUT OF A PROTOTYPE FOR DISPLAY AND KEYBOARD

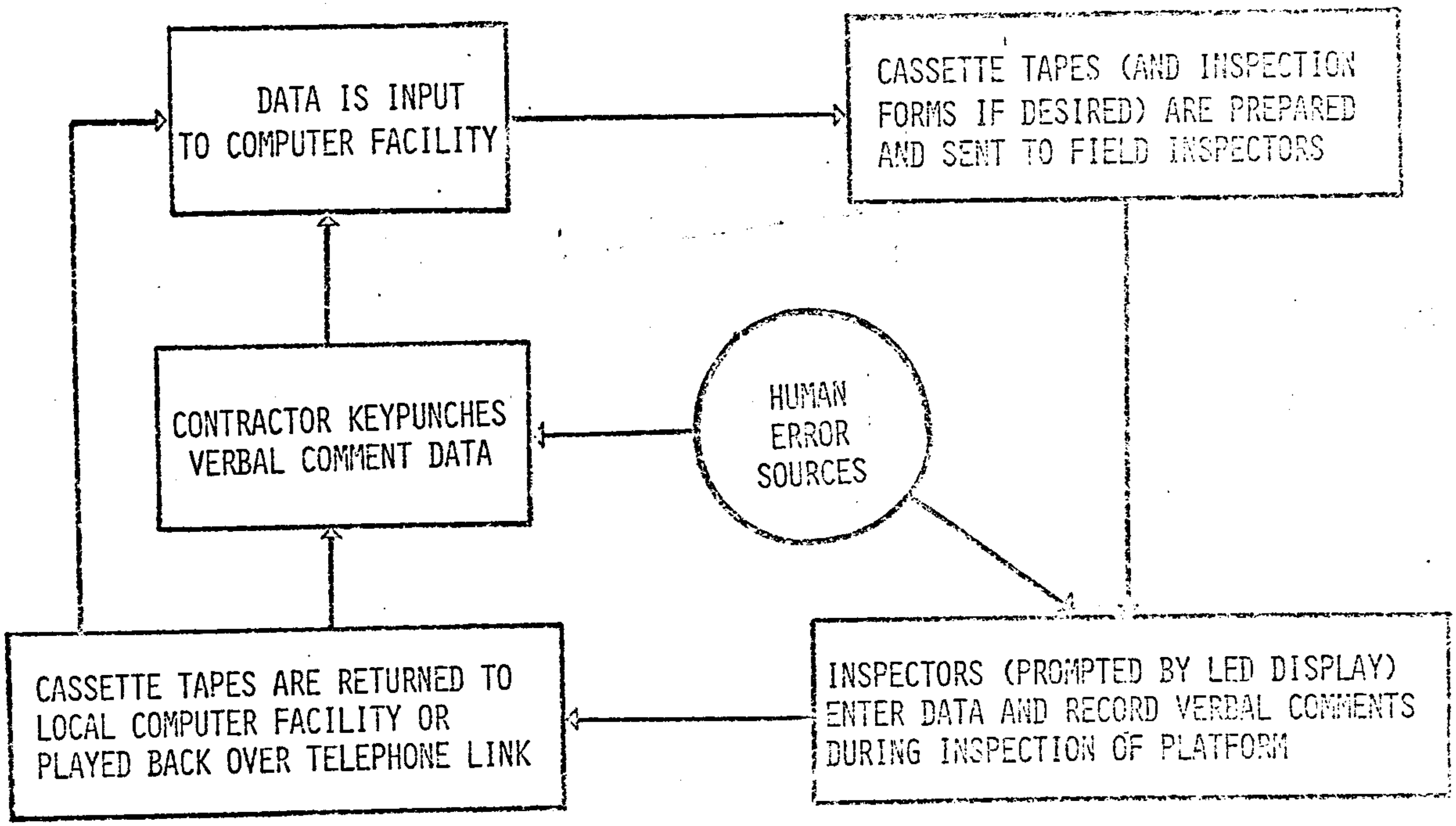


FIGURE 3. POTENTIAL DATA COLLECTION/PROCESSING SYSTEM USING PORTABLE DATA RECORDER

(2) Equipment Malfunction

Most malfunctions found by the inspecotrs are of a minor nature and can be repaired immediately on-site. The more critical malfunctions are also typically repaired immediately or at most within several days. None of the several inspectors informally interviewed at the oil platforms ever found it necessary to shut down a well or platform because of a critical malfunction.

B. Environmental Factors and Data Collection

(1) Noise Levels

The noise levels on the oil platforms vary from relative quiet to deafening noise. At the high noise levels, conversation is, at best, very difficult.

(2) Weather Conditions

In heaby or severe weather, the data/information gathering ceases. In less severe weather, the inspectors are sometimes protected by decks or overhangs. The data forms are protected, in inclement weather, by special folders purchased from the General Services Administration. Forms can get wet, muddied or torn by the wind under the best precautions, but this seems to be very infrequent and inconsequential.

C. Data/Information Characteristics

Despite the diversity of equipment and equipment configurations from platform to platform, the same basic types of information must be collected at each platform. Data must be gathered on such items as: facility/well personnel; water and drill depth; equipment and maintenance levels; oil, gas and water pressures; and, safety precautions/hazards. The data/information is recorded exclusively in one of two ways. The more frequent data entry type is typically in the form of six alpha-numeric characters or less. The second manner of data/information entry is accomplished by inspector comments (i.e., sentence format).

D. Data Source

(1) Oil company records.

Upon arriving at an oil platform, the USGS inspector's first objectives is to transcribe data that the oil company has collected since the inspector's last visit. This takes approximately 1-1 1/2 hours. At this time, the USGS inspector often discusses various problems/questions with oil company personnel which are documented in the USGS inspector's report.

(2) Indicators

(a) The USGS inspectors obtain much of their data from the numerous moving point dials located at various points on the oil platform. The majority of dials can easily be read. In some instances the indicator is a go/no-go light, i.e., green/red, which simply indicates whether a particular device is operating within designated limits or not.

(b) Indicator Operator. Most indicators are in continual operation, some must be activated (e.g., by a lever) and some indicators or actuation devices must be attached to equipment by the inspector during the inspection period.

(3) Safety Checks

(a) Specific, regular checks. As part of the inspection, there are some devices which must be checked (e.g., emergency shut-off valves, pressure devices on capped wells, etc.)

(b) General safety checks. As part of the general inspection process the USGS inspector is constantly looking for possible fire hazards (e.g., an excessive collection of combustible material), misplaced or missing tools which may be critical in an emergency (e.g., a missing wrench from an emergency shut-off station), worn/deteriorated equipment, etc.

E. Input Error Characteristics

(1) Inspector/Data Coder Errors

Discussions with the inspectors, data coders, and other USGS personnel indicate that input errors (e.g., discrepancies between the actual readings and the recorded reading) are infrequent and noncritical. The data coders at the Metaric district office stated that whenever data/information items on the inspection form are unclear, a telephone call to that particular inspector is all that is needed to define the entry.

(2) Keypunch Errors

It seems that the majority of input errors occur during the keypunching of data. (The coding sheets are sent out to be keypunched by a contractor.) The number of keypunch errors that are sent to the computer are kept to a minimum due to the two experienced coders who check the punched cards when they return from the contractor. These keypunch corrections are made at the district office. Errors of this type that escape the coders are usually detected by the inspectors when they receive the computerized forms for the next inspection. The time lapse between submission of the inspector's data forms and the subsequent inspection is typically four to six months. It is likely that only obvious errors will be identified by the inspectors after such a long period.

F. Field and Headquarters Data Processing Requirements.

(1) Field requirements.

The only data requirement apparent for the platform inspector is the need to have the previously reported inspector data at the time of a new inspection. The inspector does not require this data until the time of the inspection.

(2) Management requirements.

Managers at Headquarters, Region, district and field offices do require data/information summaries. This is typically accomplished by telephoning the computer support personnel in the Gulf of Mexico Region (this would be the Metarie District Office) and requesting the information. Computer support personnel retrieve the information from the computer and send the output through the mail. Sometimes a quick turn-around time is desirable. The mail service seems to be the limiting factor in turn-around time. For instance, output often can be produced within thiry minutes after a telephone call but the mailing procedure can taken one to three days.

3. EVALUATION OF PDR CONCEPT

A. Advantages of a PDR-Type System

There are three potential advantages to be derived from a PDR-type system. First, the need to transport inspector data forms from the field to the district office, for processing, would be eliminated. The second benefit would obviate the need for coder personnel (there are currently two coders in the Metarie district). The third, and most important advantage, is that only a minimum of keypunching would be required.

The above mentioned advantages not withstanding the disadvantages of and arguments against implementing a PDR type system far outweigh the advantages. The disadvantages and reasons are contained in the following three sections: system/human performance considerations; software requirements; and, current PDR display implications.

B. System-Human Performance Considerations

(1) Current error status and through-put requirements.

As mentioned in Section 2E, there seems to be little room for improvement in reducing error frequency or curtailing crucial errors. Even though errors occur at the key punching mode, the coders catch and correct most of the errors. Also, even though PDR would decrease the two to four week processing time from inspector input to computer storage (but not necessarily inspector input time), the current limiting factor of the through-put is still the mailing procedure (i.e., mailing the computer output from the district computer support center to its destination). Furthermore, assuming the mailing procedure is eliminated (perhaps by installing output devices at the requestor's office), there does not seem to be a real requirement for speedy data through-put (Section 2F).

(a) Inspector-platform personnel information exchange. Important information is exchanged between the inspector and the platform supervisor (or other oil company personnel) during the USGS inspector's visit. Use of the PDR to record (either by audio or keyed input) such information would be clumsy and awkward, and could change the nature of the information exchange.

(b) Noise and voice input. As mentioned earlier (Section 2B) noise levels sometimes reach very high levels. This would impede the use of the PDR audio recording feature both at the input stage and the output stage (i.e., during the tape to punch card transcription process).

(3) PDR training requirement.

In addition to learning what items need to be recorded, where to find the information on the platform, etc., (which is also required in the present system), the new inspector would have to learn how to use the PDR. This does not only involve learning which key to press and in what sequence, and how to interpret the display (see Section C on software), but it will also involve learning uncommon memory processes to retrieve and utilize the computer messages (see Section D on Display Implications).

C. Software Requirements

(1) Prompting/Feedback Software

The effective use of prompting and feedback messages and procedures is very much tied to adapting the prompts/feedback to the level of expertise of the user. For instance, not only does an experienced user not need many prompts and elaborate feedback, but he does not want and can become dissatisfied by many prompts and extensive feedback. These facts, of course, have important implications for software structure, PDR size (i.e., physical and storage capacity), and ultimately, cost. A limited prompting/feedback system, which would reduce software cost, would defeat one of the original purposes of implementing a PDR-type system.

(2) Diversity of equipment and equipment configuration.

One of the aims of the prompting procedure is to lead an inspector through the various check points in a systematic manner. Since each platform is unique, in terms of specific equipment and equipment configuration, the software effort to accomplish this aim would need to be quite large. And, with alteration of the platform or with the construction of a new one, this difficult software task would continue.

D. Current PDR Display Implications

(1) Limitations of a very small input/output display.

Software techniques such as scrolling and menu selection can be good user aids. However, the constraint of the PDR input/output display (i.e., only twenty character positions), places severe limitations on the use of these techniques by placing a burden on the user's memory. In the current method, much of the input/output is present on the data form and can easily be accessed or checked with little loss in inspector processing continuity. However, with the PDR, the inspector must retrieve data/information via the PDR keyboard. In a situation in which an inspector is simultaneously checking several inputs or terms of information, the time lapse in the PDR retrieval procedure may interfere with memory processing causing transposition, forgetting or distortion of information previously retrieved.

(2) Display-overlapping technique.

The small display is similarly disruptive of the feedback process. Feedback, especially for error correction, can easily exceed twenty character positions. Software design problems arise in trying to arrive at an acceptable overlapping technique for output. Should scrolling the display produce twenty new characters, fifteen, ten? The answer is not a simple one and will vary from user to user. A possible solution for this problem is the use of cryptic or severely abbreviated feedback. But this tends to offset the power of a computer system (i.e., presentation of feedback in a clear, understandable manner).

(3) Display readability

Reading the PDR-type could become a problem on a sunny or bright day. The display can be very difficult or impossible to read when the sunlight is reflected off the display or if the display is at a non-optimal viewing angle.

4. RECOMMENDATION FOR THE USGS DATA COLLECTION/PROCESSING SYSTEM.

A. PDR Concept.

It is recommended that USGS not implement the PDR concept. ARI's decision is based on an analysis of the USGS data collection/processing system, its current requirements and human factors/behavioral principles. The major reasons for the above recommendation are:

(1) Error frequency and critically are currently estimated to be at a very acceptable level;

(2) A requirement for rapid data processing does not exist;

(3) The diversity of oil platform equipment and equipment configuration and the necessity to update inspector prompting would pose serious software problems;

(4) The PDR concept cannot, at this time, provide sufficient flexibility for proper implementation of such techniques as prompting, scrolling, menu selection, feedback and data retrieval. The utilization of these techniques on the current (or similar) PDR device would needlessly tax memory processes.

B. Potential ADP Assistance.

If greater demands are placed on the data collector/processing, ADP assistance may very well be warranted. The following general recommendations will do much to accommodate increased data processing requirements:

(1) Interactive Terminal

Attain the capability to transcribe inspector data/information from inspector forms to computer by means of an interactive computer terminal. Basically this means acquiring a CRT terminal and keyboard which can communicate with the computer and peripheral storage (Figure 4). This capability will allow USGS to eliminate the keypunch contractor--the keypunch step in Figure 1 and Figure 3. Since the CRT will have considerably more display area it will be able to take full advantage of all the techniques and procedures offered in the PDR concept. Also, all computer input can be accomplished at the district office(s) by the personnel who currently perform data coding. In addition, with a full CRT and appropriate storage capacity, software can be written to accommodate varying levels of ADP user expertise.

(2) Headquarters Output Devices.

If one or more USGS offices has a necessity for rapid turn-around time on data/summary requests, it might be advantageous for that office to obtain an output device (such as a printer). With such a device they could still telephone in their requests but the information would be transmitted directly to their output device.

C. Platform Procedures and Equipment Alteration.

(1) Placement of indicators.

In some instances the data collection is difficult because the indicators are stationed at inconvenient locations. For example, some indicators are approximately eight to ten feet above the platform floor; some indicators reflect enough sun to prevent accurate reading; and some indicators are located in hard to reach corners and equipment areas. It is recommended that when possible the indicators be positioned so that the inspectors can easily read them.

(2) Standardization of oil company data forms.

ARI is familiar with the problem inherent in the modification of established procedures and formats which are designed to conform to standards. However, standardization of oil company data forms would decrease the time the inspector spends looking through oil company records and decrease the time for a new inspector to learn this particular aspect of the job.

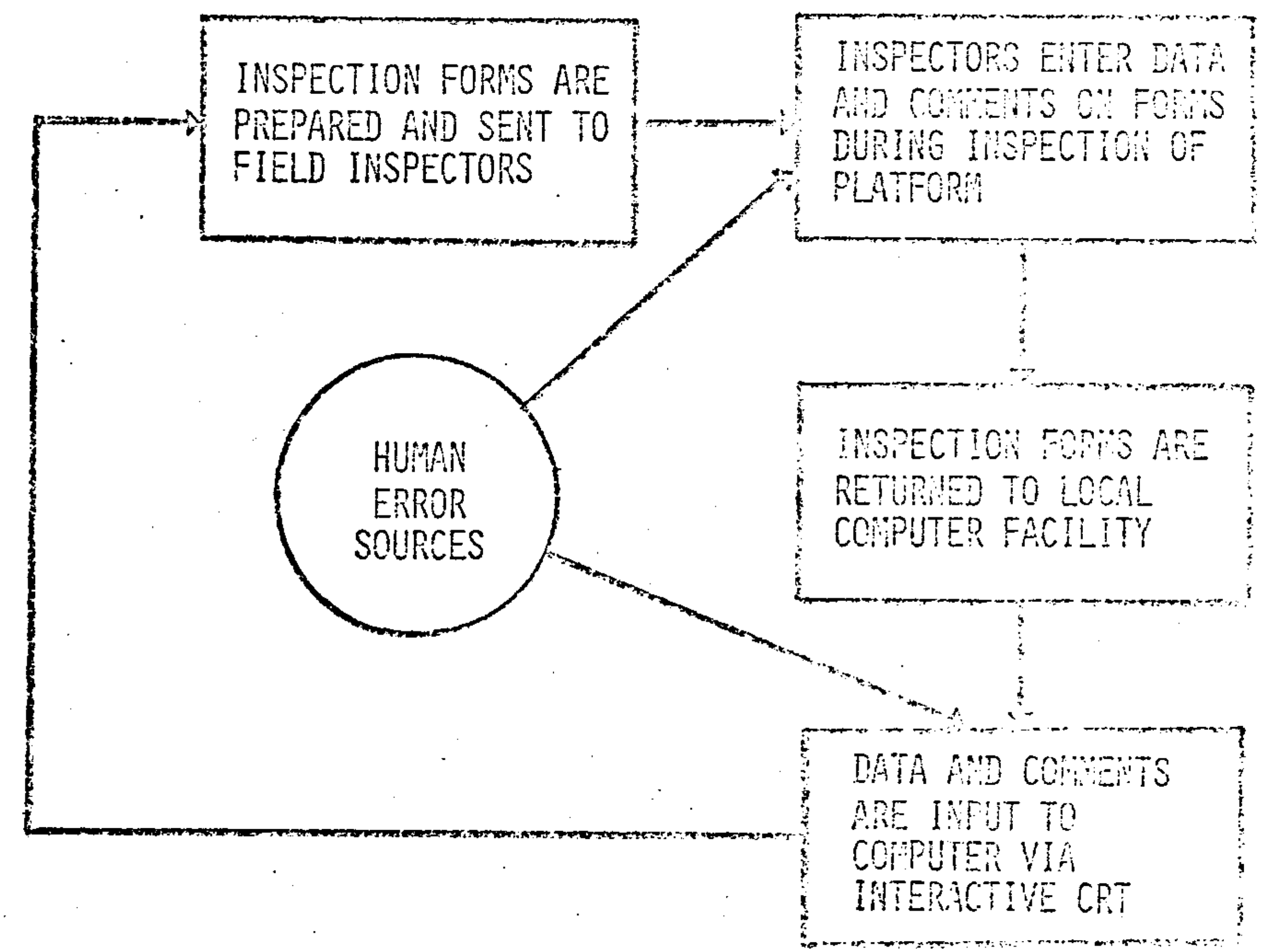


FIGURE 4. POTENTIAL ADP-ASSISTED USGS DATA COLLECTION/PROCESSING SYSTEM

5. SUMMARY

BY way of summary this section will briefly comment on thirteen operational capabilities (found in an HDL report) which are required by a PDR device. The first part of this section lists these capabilities which, in ARI's estimate, are met in the PDR concept. The second part briefly discusses those operational capabilities which are not met.

A. Operational Capabilities Satisfied By PDR Device

The following operations are met by the proposed PDR device: manual keyboard entry of digital data; editing of digital and verbal data; automatic control of tape cassette drive; data recording or playback via a telephone coupler; format check of data transmitted over telephone coupler; and, automatic generation of data summaries. However, even though the capabilities are feasible, there are not specific requirements for the speed and error reduction goals they are aimed toward.

B. Operational Capabilities Not Satisfied By The PDR Device

(1) Display digital data as it is entered.

Although in most cases the display would be readable it will not always be so. The reflection of the sun or bright light and non-optimal viewing angles may make the reading of the PDR display very difficult or impossible.

(2) Format error checking of digital data.

Due to the constraint of the twenty position feedback display the PDR concept cannot take full advantage of the spectrum of feedback messages which would take different users and instances into account.

(3) Verbal input of comments and audio playback of verbal comments.

These two capabilities are complicated by high noise levels which are not uncommon on the oil platforms. Also, recording rather than writing comments might result in excess or trivial comments.

(4) Playback and redisplay of digital data.

This capability is met as long as the data played back or redisplayed is equal to or less than twenty data positions. In most instances this will not be the case. The use of a scrolling technique to aid in this capability would place a burden on the user's memory.

(5) Prompting of inspector to aid in his progress through the inspection data acquisition process.

The type of prompting which can be done with a twenty position display is very limited. The idea of prompting incorporates the idea of adapting to the user so that short or long prompts can be given as needed. A long prompt can be an explanation of input procedure with one or two examples. In many cases the prompting message should be seen in its entirety to be most effective.

(6) Direct generation of computer data records (with verbal comments keypunched).

This capability alludes to the fact that the data record is not complete without the verbal comments. In the PDR concept the verbal comments must still be keypunched and then read into the computer. This latter contingency, then, delimits the value of the "quick" digital input.

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Phone: (612) 935-7704

NEW DATAMYTE HAS PROMPT AND REVIEW/EDIT FEATURES

In addition to the Datamyte 904 we now offer the 906, a new model that operates very much like the 904, but with two very significant new features . . . prompt and review/edit.

Use the convenient reply card to get the full details. In the meantime, however, here's a quick review of the new 906 features:

PROMPTING

The entire memory in the 906 can be pre-loaded with data from a computer, or from tape or diskettes at a terminal. The pre-load can comprise two or three fields . . . PROMPT, DATA and TIME (optional).

PROMPT FIELD: Prompts the observer with such things as machine number, employee ID, part number, etc.

DATA FIELD: Comprises a number of underscores (__), indicating that data are to be entered by the observer from the 906 keyboard.

TIME FIELD (optional): Automatically records time to .01 minute when data are recorded by keying ENTER.

The PROMPT and TIME fields cannot be altered by

NEW TIME STUDY SOFTWARE

Our revised time study program, TSTUDY, is now a mature, proven program. It will work with both cyclical and continuous studies, and it comprises some interesting features really only practical with computer-aided time studies — such as a DISTRIBUTIONS report showing all element times tabulated by ascending values, and automatic frequency adjustment of non-cyclics and repeat elements.

TSTUDY is available for $390 in three forms:

1) **Source listing** — for you to convert and load on your own computer.
2) **Time-share** — a very low-cost ($7/hour, no CPU charge) nationwide service bureau system.
3) **Microcomputer** — a minicassette for the Computer Devices Inc. Model 1206 portable microcomputer.

Future programs will include Work Sampling (soon), Downtime Recording, GTT, and MTM-3.

GET COMPLETE DETAILS IN NEW DATAMYTE BROCHURE

New 12-page brochure (#116) presents most of the details on features/benefits, accessories, applications, operation and specifications. It also provides an insight into what else is needed besides the Datamyte 900.